Towards a Neuroaffective Approach to Healing Architecture

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This thesis, which is a monograph, has been submitted for assessment of the PhD degree. However, the papers listed above has been submitted for publication, based on the thesis, and is included in an appendix to the thesis. As part of the assessment, co-author statements have been made available to the assessment committee and are also available at the Faculty. The thesis is not in its present form acceptable for open publication but only in limited and closed circulation as copyright may not be ensured.

“In any field find the strangest thing
and then explore it.”
-John Archibald Wheeler

“Things that are obvious are not necessarily
true,
and many things that are true
are not at all obvious”
- Joseph LeDoux

“The art of research is the art
of making difficult problems soluble
by devising means of getting at them”
-Sir Peter Medawar

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Danish summary

I de seneste år har den opfattelse vundet frem, at arkitektonisk design af hospitaler kan influerer på patienternes helbredelsesforløb. Disse ideer er kommet fra to relativt uafhængige kilder, nemlig Evidens Baseret Design (EBD) og individuelle forfattere blandt medicinske forskere. EBD har imidlertid som en del af sin etablerede metodik, at arkitekturen, f.eks. sengestuer, holdes som en konstant i stedet for at være en variable i undersøgelserne. Dette har betydet, at disse undersøgelser har givet meget lidt information om en eventuel virkning af det arkitektoniske design. Ydermere ligger det i den metodiske tilgang EBD anvender, at der kun ses på de fysiske årsager, f.eks. dagslysmængde, og det målbare fysiologiske resultat, men ikke på hvilke fysiologiske mekanismer der medierer den målte effekt, hvilket har gjort det vanskeligt at generalisere fra EBD undersøgelser. I modsætning hertil har de forfattere blandt medicinske forskere der har skrevet om emnet naturligt demonstreret stor forståelse for de bagvedliggende fysiologiske processer, men har veget tilbage for en systematisk sammenkædning med arkitektonisk design. De beskrevne forbindelser mellem de fysiologiske mekanismer og arkitektur har dermed ikke været overbevisende. Det er således denne afhandlings mål, at yde et videnskabeligt bidrag til etableringen af en forståelse af, om arkitektonisk design i sig selv kan påvirke fysiologiske processer, således at helberedelsesprocesser kan påvirkes herigennem.

Udgangspunktet er begrebet ’den homestatiske balance’ er centralt for helbredelse og helse generelt. Enhver levende organisme er stillet over for den udfordring, at dens indre biokemiske miljø skal holdes inden for snævre rammer, på trods af trusler i det ydre miljø’s og den foranderlighed det repræsenterer. Kompromitteret helbred kan derfor forstås som en tilstand af homeostatisk ubalance.

Forskningsindsatssen er derfor koncentreret om at finde mekanismer der binder perception og homeostatisk regulering sammen. Her vælges kroppens stress systemer som udgangspunkt for den videre forskning, da stress kan forstås som en tilstand a truet homeostase, og en stress reaktion som en adfærd, hvormed organismen søge at eliminere truslen. Desuden er der en omfattende interaktion mellem stress systemerne og immunforsvaret. Spørgsmålet er derfor, om de arkitektoniske omgivelser til en stressfuld begivenhed kan influerer på hvilken størrelsesorden stressreaktionen får. For at undersøge dette, blev der udført et stress eksperiment hvor en virtuel version af den såkaldte Trier Social Stress Test blev anvendt. Fordi testen blev udført i et virtuelt miljø, kunne udformningen af arkitekturen varieres systematisk, og der blev således anvendt henholdsvis et lukket rum og et rum med åbninger. Resultatet blev, at der kunne måles et signifikant lavere niveau af det immunregulerende stress-hormon kortisol hos forsøgspersoner der gennemgik testen i det åbne rum, end dem der gennemgik den i det lukkede rum, hvorimod der ikke kunne måles forskelle på reaktionen fra kroppens andet stress-effektor system, det sympatiske nervesystem.

Der er således skabt en forståelse af, hvorledes systematisk variation af arkitekturen gennem en veldefineret fysiologisk mekanisme kan føre til reaktioner, der har betydning for helse, velbefindende og helbredelse. Det skal dog nævnes, at stress testen kun inducerer akut stress, der har en anderledes effekt på immunsystemet end langvarig stress, og desuden blev kun unge mænd med godt helbred testet, på grund af alders- og kønsforskelle i stress reaktions mønster. Således demonstrer forsøget, at arkitektur kan gøre en forskel med hensyn til kortisol, men at der er behov for yderligere forskning for at en dybere forståelse af interaktionen mellem perception af arkitektur og fysiologi kan opnås.

Under alle omstændigheder, er teorien om, at det kunstige menneskeskabte miljø som arkitektur udgør, kan influerer på fysiologiske reaktioner gennem design, blevet styrket.

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English summary

In recent years, there has been a growing conception that the architectural design of hospitals can help to promote healing processes among patients. These ideas have come from two relatively independent sources, namely Evidence Based Design (EBD) and the writings of individual medical researchers. However, as EBD tends as a methodological approach to keep the architectural framework e.g. patient bed rooms as a constant instead of a variable, very little information is gained about the possible effect of the architectural design itself. Furthermore, as EBD tends to concentrate on physical causes and physiological effects, while disregarding the physiological processes that mediate the demonstrated effects, it often becomes rather difficult to generalize from the results. On the other hand, a couple of medical researchers have presented ideas about how architecture might influence healing and promote health. In the case of these writers, the understanding of the physiological processes is very robust, but a systematic understanding of the link to architecture is missing. Thus, a consistent understanding of how the perception of architecture through physiological mechanisms might influence healing is missing. It is therefore defined as the aim of this thesis, to make a scientific contribution to the establishment of such an understanding.

It is established that the concept of the homeostatic balance is central to the concept of health and healing. Any living organism is faced with the challenge to keep its inner biochemical milieu stable within narrow bounds despite the relatively large fluctuations and physical threats that might occur in the outer environment. Compromised health can be understood as a state of homeostatic imbalance.

Research is then concentrated on finding mechanisms that tie together perception and homeostatic regulation. The stress systems is picked for further investigation, as stress

basically can be defined as a state of threatened homeostasis, and a stress reaction as an adaptive behavior. Furthermore, there is a comprehensive interaction between the stress system and the immune system. The question is then, if an architectural context to a stressful event can influence the magnitude of the stress reaction. To investigate this, a stress experiment is carried out, using a virtual version of the so-called Trier Social Stress Test. Because the test is carried out in a virtual environment, the architecture can be systematically varied. Using a closed room versus a room with openings, it is shown that differences can be measured in secretion of the hormone cortisol, which is a stress hormone as well as an immune regulatory hormone, but no differences can be measured in the reaction of the other stress effector system, the sympathetic nervous system.

Thus, an understanding of how systematical variations in architecture through a well-defined physiological mechanism can influence health, healing and well-being is successfully established. However, the stress test only induces acute stress which has a different effect on the immune system compared to prolonged stress, and furthermore only young healthy males were tested due to age and gender differences in stress reactions. Thus, the experiment demonstrates that architecture can make a differences as far as cortisol is concerned, but that further research is needed to reach a comprehensive understanding of the interaction of the perception of architecture and physiology, along these lines.

However, the theory that the artificial environment that is constituted by architecture can influences physiological reactions such as stress reactions through their design is strengthened.

4

Personal motivation and acknowledgments

This thesis has come out of a personal motivation; of questions that have emerged and grown through my professional carrier. Questions that I think I share with many of my colleagues and with many others that through their profession belong to the same industry as me or otherwise are involved with it. Although the thesis in the end might not come up with any final answer but turn out to be just a small step, I have taken the liberty to think that pursuing these personally motivated questions might be of sufficient benefit of others.

This of course calls for an explanation.

I am an architect. I have worked for 25 years as a practicing architect, 24 years within the same office, and the last ten as a partner. The office was, and still is, a typical Danish provincial office with 20 to 25 employees relying on the economic conditions. Although we made all kinds of building types within the local area, we had a special expertise that enabled us to serve clients on a regional and national scale. Among those were hospitals and health care buildings in a broader sense, like nursing homes.

In contrast to the popular belief that one frequently meets that architecture is about making buildings look flashy and impressive, architecture is the resolution of many different, often conflicting parameters, among those of course an appropriate appearance

inside and out. The handling of this multitude of parameters makes the ability to make choices, priorities and compromise in an informed way an important issue for any architect. Human beings are a species with the capability to adapt the environment to suit own needs instead of the opposite. In the general division of labor by which society is organized, it has to a large degree become the responsibility of the architect to carry out the part of this task of adapting the environment related to our physical surroundings, in terms of the layout of buildings and cities on behalf of society. This is quite a responsibility, which demands a deep respect for society and an obligation to develop professionalism and expertise, and to gather knowledge.

Part of what we believe architecture can do, and what we consequently see as an inseparable part of our job, is to affect people. With great confidence we tell clients, users, investors, authorities, citizens and whoever else cares, how we imagine a given project will affect them. We imagine places that make people feel calm, dignified, cheerful, informal, dynamic, beautiful, comfortable, ceremonious, grave, cozy or whatever else may be on the human palette of feelings. Sometimes it turns out as expected, but - I guess every architect has to admit - sometimes it doesn't. Sometimes we apparently overestimated what architecture can actually do, sometimes we underestimated it, sometimes we misjudge it, and fortunately many times we are successful. The point is that we in many instances do not have any instruments apart from our own experience and imagination to guide this judgment, and we do not have any clear picture of what can and what cannot be achieved through architecture. I guess that this makes any responsible and ethically minded architect ask him- or herself: "how do I actually affect other people with what I design, and what can I actually promise to accomplish".

For me these questions were put on the edge by working within the hospital sector. Certainly, many doctors have a quite mechanistic view of the human body. I have however also met doctors, usually with a long clinical experience as well as experience within research, who think otherwise. Among those who have influenced me, and to whom I owe gratitude, is leading chief physician Per Thorgaard at Aalborg Hospital dep. Nord, who has for many years experimented successfully with the use of music in clinical practice and in ambulances. I also remember with pleasure a visit to the ICU at

Rigshospitalet (the biggest and most specialized hospital in Denmark) where the chief physician and at that time head of research at Rigshospitalet Lars Hesleth, gave an inspiring guided tour demonstrating his work with music and art. Lars Hesleth was also co-author and co-editor of the book “Sansernes hospital” (“The hospital of the senses”), which was an early inspiration. On several occasions I have been fortunate to work together with the now retired chief physician Ib Hessov, who as a researcher has contributed substantially to the dramatic shortening of hospitals stays in Denmark. Ib has always insisted on integrating art in hospital design and supported it with his comprehensive clinical experience.

As an architect, I came to wonder if experienced doctors like these think that music and art can influence the healing processes of sometimes badly wounded or seriously ill patients, and on several occasions have successfully documented it, what about architecture? If we think that architecture has the power to affect people the way we do – does it also affect the health of people, and if it does, what a responsibility. Not only patients but people in general spend most of their time in and around buildings. Do we more or less randomly affect them not only psychologically, but also physiologically?

In 2007 – 2008 I was project manager for the design of a new ICU at Århus hospital. We had just finished a large emergency department at the same hospital where we very successfully everyone agreed, had collaborated with an artist.

At a certain meeting in the building committee in the fall 2007, which should turn out to be crucial for me, Ib started to talk about integrating art into architecture, as usual. A skeptic among the doctors proposed that the effect should be measured and documented, just as it would have been done with a new treatment or a new drug. I had some years previously taught some hours at the department of Architecture and Design at Aalborg University alongside my job at my architectural office, and mentioning this, I was given the job to contact the department. An agreement was settled and an application for funding was sent. To our surprise we got more funding that we had applied for, and also an additional assignment: to make a report on the state of the art of the topic. The result was the report “Helende Arkitektur” (“Healing Architecture”). I was fascinated by being involved on a research level with these questions that had puzzled me more or less since I was studying architecture. I used the opportunity of the hours spent on driving back and

forth to the meetings with the head of department Michael Mullins who helped me a lot, to pave the way for a career shift. Finally, I was able to sell my share, leave the office and get employed at the university, and as a first encounter with research, participate in the "Helende Arkitektur" project. The following couple of years I mainly taught, but not being entirely satisfied with the "Helende Arkitektur" project, I started reading, thinking of and writing on this thesis. In 2011 I was enrolled into the doctoral school of Aalborg University to finally make a Ph.D of my efforts. As a consequence of my enrollment, I was allowed to have supervisors, and I have a lot to thank my supervisors Poul Henning Kirkegaard and Åse Marie Hansen for – the academic world is demanding, and to an outsider, the learning curve tends to be quite steep at times.

I connection with the "Helende Arkitektur" project I also meet Dr. Roger Ulrich who has played a crucial role in forming the movement "Evidence Based Design" which is basically the method behind most of the studies in "Helende Arkitektur". Roger, who now lives in Sweden and is a part-time professor in Aalborg, has been a kind of mentor throughout the process, and I thank him for many interesting conversations.

So, the thesis is the product of a personal wonder caused by my professional work as an architect. A question about how and to which extent architecture has the potential to affect people that I think I share with many. A question of which the importance has been greatly increased by the growing suspicion, that the ability to affect people with architecture also includes their physiology.

Although on the surface it seems to primarily address knowledge from several sciences perhaps not normally associated with architecture, the thesis is on architecture addressed at the architectural profession. If it can be of benefit to those who work professionally with architects, and perhaps even evoke interest among those from the numerous other faculties of knowledge that have been drawn upon, it will be a most welcome bonus.

5

Initiating research questions

In the preface, the question was raised about how far reaching the influences of architecture actually is - does it even include the human physiology. However, seen from a research point of view, the questions was raised in a lay-man's voice, the voice of a practicing architect on the basis of personal experience. In this chapter, the question is sought to be brought into a more clarified form, which is usable as a startingppoint for the long research process of searching for answers.

Architecture is not a precise term, but a term which through its use has acquired different meanings in different contexts. Before the process of concretizing these quite loose considerations can be started, it may therefore be helpful to decide on a definition, at least as a temporary basis for the thesis.

Architecture will in this thesis be understood as the part of the artificial, man made environment that can be termed as buildings, that is to say not landscape, not cities and not design items. This means that for example definitions which use aesthetic quality to distinguish between ordinary buildings and buildings which possess architectonic qualities, such as Le Corbusier's:

"You employ stone, wood and concrete, and with these materials you build houses and palaces. That is construction. Ingenuity is at work. But suddenly you touch my heart, you do me good, I am happy and I say: "This is beautiful." That is architecture. Art enters in."

(Le Corbusier 1978, p.141)

are considered too imprecise for the time being. The question then is whether health can be manipulated through the perception of the built environment. This further requires a

definition of what is understood by perception. In this thesis the definition by Daniel Schater (2011) will be used: “perception is the organization, identification, and interpretation of sensory information in order to represent and understand the environment”.

As a point of departure, the basic question that came out of the personal wonder described above therefore is quite broad and can be formulated like this:

- *Can the perception of architecture affect health?*

Which is a subset of an even broader question:

- *Can the perception of architecture affect us physiologically?)*

These questions are of course much too broad to be answered fully within this thesis, and they will be much delimited as the thesis proceeds.

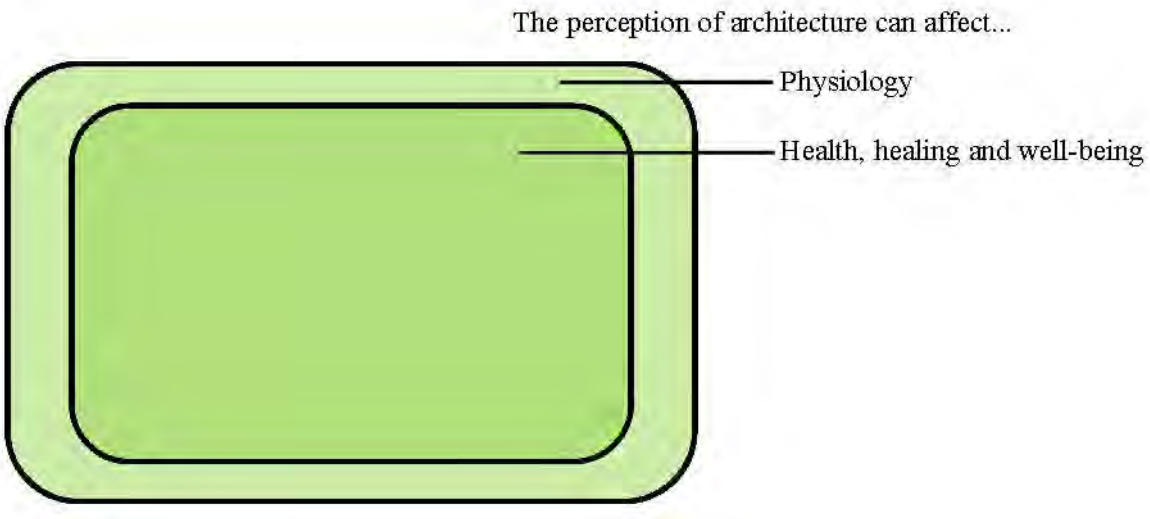

Fig.5.01. The question “Can architecture affect health?” can be seen as a subset of the broader question “Can architecture affect physiology?”

6

The role of architectural research

The thesis was initiated by a personal question. However, research is rather than a personal matter an integrated and important part of society, which calls for an understanding of the particular role of research within the specific discipline it operates – in this case architecture. In this chapter, the general role of research in the relation to society and the discipline of architecture will be discussed as well as what the particular meaning of it is in the context of this thesis.

The initial research question as it is stated in the previous chapter is formulated on the basis of these assumptions: A vague feeling that some kind of link between people's health, sense of well-being and the physical context in which they happen to reside exists. The task of this thesis then is well reflected in this statement by Josep LeDoux: “Sometimes, intuitions are just wrong – the world seems flat but it is not – and science’s role is to convert these commonsense notions into myths, changing truisms into “old wives tales”” (LeDoux, 1999, p. 12); - it is to examine whether the truism that some architecture can influence health and well-being is an “old wives tale” that has to be given up and forgotten, or whether it in fact is scientifically explainable. A systematic approach is required to turn these assumptions from a state of a vague sense into something that could be termed scientific knowledge. A systematic approach that must be attained before further progress towards answering the initial questions can be made. In this chapter through to chapter 8, the systematic scheme that will form the basis of the inquiry of this thesis will be developed and discussed. As the thesis is on architecture, firstly the role and boundaries of research in architecture will be discussed and, as far as this thesis is concerned, defined. Secondly, a systematic inquiry, an epistemological framework capable of meeting the demands of architectural research of this sort will be developed and discussed. Only when this systematic inquiry is established, it will be possible to move on to the scientific inquiry itself, which will happen in the following chapter 9 – 14.

As indicated in the introduction, the point of departure is recognition of a need for instrumental knowledge that can help to predict whether a desired effect will be achieved, or whether or not such an effect is at all achievable through architecture - in the case of this thesis with focus on physiological effects. These aims naturally define a certain approach to architectural research with emphasis on predictability, while others with other aims, such as for example the history of architecture, the role of architecture as a cultural phenomenon within society etc. might chose other approaches. Architecture is a diverse and multifaceted phenomenon, which will call for a diverse range of research methods used independently or in combination, depending on the task. However, the aim must be to find an epistemological framework that is valid and suited for the search for answers to the particular questions asked in this thesis.

Inspiration for a clearer understanding of the role of research within the industry of architecture can be drawn from a discipline like economics, which just like architecture hovers between being an exact science and being 'psychological'. The economist, John Neville Keynes who, instead of the usual two categories, distinguishes between three types of economic theory, namely a positive science understood as "a body of systematized knowledge concerning what is", a normative science understood as "a body of systematized knowledge relating to criteria of what ought to be" and the art of economics. (Keynes 1999 pp. 21-22).

Likewise, a distinction can be made between a positive science of architecture, architecture as a normative phenomenon and architecture as an art in a broad sense of the word.

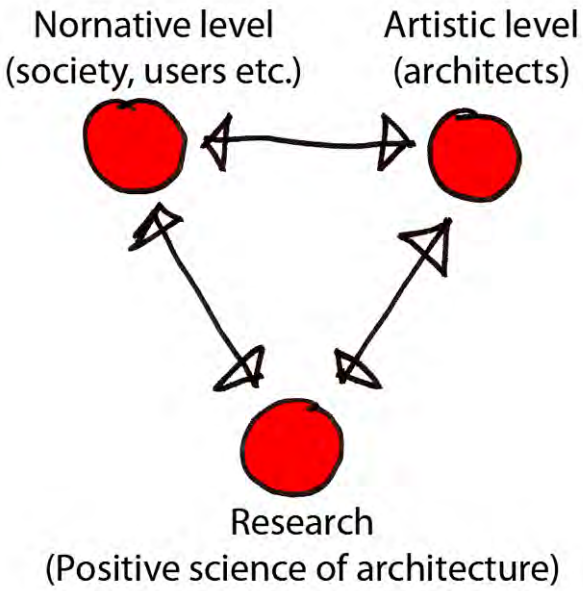

Fig. 6.01 Schematic representation of the relationship between the normative level, the artistic level and positive science of architecture.

6.1 The normative level

The normative level is thus what defines the requirements that architecture should strive to fulfill aesthetically, affectively, functionally, economically and otherwise. In a democratic society like ours, it is to some degree practically everybody, while in other societies with other political structures it has been subject to strict governmental or religious control. Highly developed and institutionalized procedures have been developed within society to accommodate these processes on many levels, like public hearings and involvement of the political level in the various levels of public planning, methods and procedures for user involvement, architectural competitions and so on. Highly developed legal systems govern the relationship between architect, client and public authority, balancing individual interests with the interest of society concerning economic and functional as well as aesthetic norms. An ever more developed educational system

ensures that expertise is available concerning most if not all technical, economic, environmental, legal and architectural issues involved in the process.

6.2 The artistic level

The role of the artistic level for the architects is to make “what ought to be” happen. The communications between the normative and artistic level are therefore much about the demands of society, owners and users. However, in practice the communication has the form of a dialogue where the artistic level has the role of identifying new possibilities from the local level to the level of the visionary projects, as well as writings like those of Le Corbusier, Aldo Rossi, Robert Venturi, Rem Koolhaas, Juhani Pallasmaa, Peter Zumthor and many others. These writings, important to the profession and to the public debate, should not be mixed up with research, as they are not striving to describe an objective reality, but rather to propose new visions for society. They have the form of subjective opinions and would hardly gain by being subject to the restrain of any research methodology. Nor would it be relevant or beneficial. It is more than implied by Christoffer Frayling (1993) and by Groat and Wang (2002, pp.107-108) that the political attention devoted to research and the resulting conditions for funding and academic recognition have meant an attempt to redefine such subjective statements belonging to the artistic level as research. However, in view of the great importance this type of subjective statements has had historically for the craft of architecture and the service it has been able to offer society, it might be more beneficial if the artistic, subjective statement and discourse were reinstated as something important to society in its own right, alongside scientific research. This thesis however belongs to the realm of scientific research.

6.3 The positive science of architecture.

If science is said to refer to an objective reality (Groat and Wang 2002, p. 22), science in itself can never make subjective decisions, as this would imply an objective right or wrong, and make all the democratic and other institutions established for making these decisions obsolete. The role of the positive science of architecture will then be to lend predictability to the normative and artistic level to ensure more informed decisions. The

role of the positive knowledge of “what is” is *not* meant to replace but to *support* the normative and artistic levels.

Perhaps it is worthwhile to emphasize that ‘positive science’ is not necessarily to be associated with positivism. Positivism is one way of acquiring positive knowledge but not necessarily the only one, and thus positivism in its various forms might be seen as a subset of the positive sciences. What distinguishes “a positive science” is rather that: “Positive theories are descriptive and explanatory systems that, because they can identify causal links, can predict future behaviors of the objects in question” (Groat and Wang, 2002 , p.78).

There are numerous examples of how lack of knowledge about what can and what cannot be achieved through design, might lead to uninformed, biased or asymmetric decisions and prioritizations. Detailed research analyzing the decision and prioritization processes in several nursing home projects (Knudstrup, 2008) reveals that elements of the design intended to meet normative program demands concerning the health and well-being of the inhabitants are made to give way to economic or legally based concerns. This happens because no knowledge is available that can ensure that the desired effects will be achieved or are achievable at all, and therefore nobody faced with a demand to prioritize knows “if it’s worth the money”. In this way, the prioritization as it is reflected in the finished building becomes grossly asymmetric in as much as the purpose that initiated the decision to build it in the first place – the nursing of elderly people – comes to play a subordinate role.

In the context of this thesis, the value of the results might be to, *if* architecture actually can influences physiology, to document it and if possible, start delivering theories, that might predict these possible effects, in order to support the artistic and normative level in design decisions as well as when it comes to prioritizing.

7.

A historical overview of the search for positive knowledge in architecture

The search for positive knowledge with the aim of understanding the nature of architecture, and make it possible to predict the outcome of a design endeavor is by no means new. On the contrary, it has been an integrated part of the western architectural tradition for at least two millennia, and has been conducted throughout history based on the understanding of what knowledge is, characteristic for each age. In this chapter, the role of positive knowledge within the western tradition of architecture will be examined through a brief historical account, with the purpose of understanding what role it may play in today's architectural research.

Much of the debate of what defines research into architecture takes Frayling's paper "Research in Art and Design" (1993) as a point of departure. In this he treats architectural research as a most recent phenomenon, which has emerged "largely as the pragmatic result of decisions about government funding of higher education". He suggests three kinds of research which might suit this new phenomenon: 1) Research into art and design, which includes research within the history of architecture, aesthetic and perceptual research and research in theoretical perspectives, 2) research through art and design, which constitutes research into materials, development work and action research and 3) research for art and design which implies the production of actual artifacts and might actually, according to Frayling not be research at all.

The search for theories that can do just what is demanded of positive theories: to predict the effect of future buildings and to explain how these effects are achieved, seems to be completely absent on Frayling's list. However, far from being a recent phenomenon, this urge to gain positive knowledge is by no means new. On the contrary, it has been conducted within the western tradition for as long as written sources date back,

characterized by the methods and concepts of knowledge typical for the different eras. There is a long tradition of treaties on architecture with this purpose, with the Roman architect Vitruvius (80 – 15 BC.) as its prominent starting point. As Vitruvius writes in the preface to his "Ten Books on Architecture" addressing the emperor Augustus: "I have drawn up definite rules to enable you, by observing them, to have personal knowledge of the quality both of existing buildings and of those which are yet to be constructed" (Vitruvius 1960, p.4). Thus, the need for positive knowledge to sustain design has always been felt and has always had a role to play, though it has differed a lot depending on the different concepts of architecture that have prevailed throughout history.

To borrow the phrase 'paradigm' from Thomas Kuhn's theory of the development of science (Knudsen 2005, p. 120-121) at least two architectural 'meta-paradigms' can be identified. They could be termed 'The divine-centered paradigm' and 'The human-centered paradigm'.

7.4.01 The divine-centered paradigm

The divine-centered paradigm stretches from pre-history to the Enlightenment. However, Vitruvius was the first known theoretician to write a treaty on architecture that implies a belief in the possibility to predict the quality of buildings yet not in existence. We can therefore be confident that the realization of the usefulness of predictability in architectural design dates back at least to the Romans.

The Romans regarded nature as one big system expressing a divine order, and architecture as well as human life as such were seen as an unfolding of the divine will (Norberg-Schulz 1980 p. 55). To Vitruvius, successful architectural design must have meant to be as much in accordance with the "divine will" as possible. The ambition behind the theoretical introduction to his ten books with his famous definition of architecture as consisting of "commodity, firmness and delight" must be seen as an attempt to grasp this all-encompassing order, and bring it onto a formula that enables architects to design in accordance with it.

The idea of the divine as the basic source of knowledge continues in different variations into the Christian era. Romanesque architecture strived to establish divine order on earth

related to the build-up of a society based on the church (Norberg-Schulz 1980, p. 91). Gothic architecture moved on to embody the structure of cosmos as perceived by scholastic philosophy, thereby striving to embody the meaning of existence by spiritualizing matter itself (Norberg-Schulz 1980, p. 111. Trachtenberg & Hyman 1986, pp. 225 -233). Renaissance theory strives towards an abstract architecture of ideal geometry. In contrast to middle age philosophy and architecture, renaissance conception is based on the idea of spiritual and intellectual freedom of the individual, human reason and independence of the supernatural (Trachtenberg & Hyman 1986, p. 281; Norberg-Schulz 1980 p. 128). Where Gothic architecture strived to embody the divine cosmic order, renaissance architecture rather seeks the individual expression of it. The new tendencies of humanist philosophy transformed the medieval Christian vision dramatically (Trachtenberg & Hyman 1986, pp. 281) and the individuality of Renaissance man results in that the "Renaissance divine perfection no longer consisted in the transcendence of nature, but was found in nature itself. Natural beauty was understood as an expression of divine truth, and human creativity was given an importance which approached the creative power of God himself." (Norberg-Schulz 1980 p. 128). Thus the new humanistic renaissance philosophy was basically in conflict with medieval philosophy of the church; a conflict that announced a major change.

7.4.02 The human-centered paradigm.

While baroque architecture that in many countries followed the Renaissance largely is associated with the Counter Reformation, the Reformation and the breakthrough of the Enlightenment meant a collapse of the underlying religious concept of architecture. The result was an inadequacy to find architectural expressions corresponding with the new worldview, and a restless search for a new foothold began (Norberg-Schulz 1980 p. 168-169). This lasted more or less until the modern movement in the beginning of the 20th century. The seemingly chaotic diversity of approaches in the period between the breakthrough of the enlightenment and the modern movement has made many scholars treat the period as one, although it covers both the Enlightenment as well as its opposite, the Romantic area. (Trachtenberg & Hyman 1986, p. 388; Russel 2004, pp. 615 – 622).

However, a new paradigm was established towards the end of the Enlightenment. The turning point came with the theoretician, Marc-Antoine Laugier's (1713-1769) "Essai sur

l'architecture". It proposed a new basic concept for architecture, which proved to be decisive, although the theory did not fully unfold until the arrival of the modern movement where "ultimately it provided a theoretical basis for later Modernist" (Trachtenberg & Hyman 1986, p. 408). Laugier was fully aware of the situation and the colossal task he had set out to take on , as he wrote in the introduction: "There is no work as yet that firmly establishes the principles of architecture, explains its true spirit and proposes rules for guiding talent and defining taste." (Laugier 1977, p. 1), and his answer was in line with the rationalism of the Enlightenment, as he wrote: "It seems to me that in those arts which are not purely mechanical, it is not sufficient to know how to work; it is above all important to learn to think. An artist should be able to explain to himself everything he does…..". (Laugier 1977, p. 1).

The first chapter of the book termed "General Principles of Architecture", which has by far been the most influential part of the book, consists of a myth. In fact, large parts of the rest of the book, dealing with such issues as the low morale of contractors and the like, can rightly be accused of teaching "only what was practiced in his time", which is exactly what he blames Vitruvius for (Laugier,1753/1977, p. 2). At the time, using the form of a myth was common in texts on philosophy and political theory and it is to be understood metaphorically, as a kind of "ceteris paribus"– nobody ever imagined the myths to present any concrete reality (Russel 2004, p. 626). Laugier imagines "man in his primitive state" resting in an idyllic place on a stretch of grass along a "quietly flowing brook". Soon however the idyll is spoilt: "...he thinks of nothing else but enjoying the gift of nature; he lacks nothing, he does not wish for anything. But soon the scorching heat of the sun forces him to look for shelter. A nearby forest draws him to its cooling shade;…" (Laugier 1977, p. 11). Although his discomfort due to heat is resolved, new problems soon arise: "…soon, torrential rain pours down on this delightful forest…….; he creeps into a nearby cave and, finding it dry, he praises himself for his discovery" (Laugier 1977, p. 11). However, his problems are not over yet: "But soon darkness and foul air surrounding him make his stay unbearable again" (Laugier 1977, p. 11). This last disappointment leads to the creation of architecture: "He leaves and is resolved to make good by his ingenuity the careless neglect of nature. He wants to make himself a dwelling that protects, but does not bury him. Some fallen branches in the forest are the right material for his purpose; he chooses four of the strongest, raises them upright and arranges them in a square; across

their top he lays four other branches; on these he hoists from two sides yet another row of branches which, inclining towards each other, meet at their highest point. He then covers this kind of roof with leaves so closely packed that neither sun nor rain can penetrate. Thus, man is housed. Admittedly, the cold and heat will make him feel uncomfortable in this house which is open on all sides but soon he will fill in the space between two posts and feel secure." (Laugier 1977, p. 11 - 12).

The myth systematically presents a series of problems in the form of unsatisfactory states, which are resolved by systematically changing the situation, first by the gradual movement through the different natural settings, and subsequently as architectural solutions. Furthermore, all unsatisfactory states relate to his body. When turned into architecture, the solution to each problem results in a particular class of architectural elements, where construction has a special status as the prerequisite for all other solutions. Thereby a precise relationship between needs and architectural composition is established, and, as the elements are generated in a logical sequence, a precise hierarchy is established among them. Laugier did certainly not imagine that man only needed shelter, shade and good air quality. Later in his book more needs are added, related to the building's functionality and its relation to its surroundings, providing interesting observations like "..a dull view deepens or causes melancholy" (Laugier 1977, p. 81). Thus Laugier's text is not a book of rules, but rather a method for establishing architectural order on the basis of human needs. What he has introduced is first and foremost a model describing his proposal for a new conception of architecture, its elements and value system: a) construction as the prerequisite, b) the building envelope as the means to mediate between the interior and the surrounding environment, c) and the human body as the defining cause.

This is the decisive moment of paradigm shift – man has gained a new foothold and has replaced God as the yardstick of architecture. This could be called the *human-centered paradigm*. Although he simply articulates what was a general trend concerning the paradigm shift in the Enlightenment in architectural theory, Laugier is the very first to do this in writing, which is what makes him particularly interesting in this context ,with regard to all that happened after him. As a consequence, architectural research becomes research about humans' reaction or interplay with architecture, which we in most

instances take for granted today. All sciences that deal with humans are at hand to choose from, depending on which aspect of humans is relevant for the relation to architecture under investigation.

An example of how the ideas established by Laugier came to provide a theoretical basis for the breakthrough of the modern movement is the architecture of Le Corbusier, who has followed this method of letting each identifiable human need result in a class of architectural components rather consistently. From his Domino concept of 1914 and onwards almost all, if not all, of his designs follow the strategy of being a kind of three dimensional collages of architectural elements each serving a particular human need or providing a constructional precondition for it. In his 'white' architecture of the pre-war period the elements almost entirely address basic needs in quite a straight forward Laugier-like fashion, but in his post-war architecture "object à reaction poétique" increasingly turns up in his buildings to fulfill 'higher' needs as well. (Moss 1982, pp. 285-290). A lot of great architecture has been made that doesn't follow these strategies so consistently, but the example of Le Corbusier demonstrates that the road from research to design does not need to be insurmountably long. Much of the strength and feeling of meaning and significance - a recognized characteristic of Le Corbusier's architecture - no doubt stem from the fact that all elements address something meaningful to humans, and as they are separated and only carry one unique message each, none is 'semantically overloaded'.

8

Epistemological approach.

Architecture is by nature a multi-disciplinary endeavor, as it addresses almost all aspects of human life. Research in architecture, in as much as it reflects this situation, therefore must by nature also be multidisciplinary. As a research question, however broad it might be is not likely to include the total phenomenon of architecture, the methodological approach must be carefully considered depending on the research task.

It has now been argued, that the research in architecture within the human-centered paradigm is primarily research in humans. Furthermore, it can be said, that a positive science of architecture in this context is about being able to predict human response.

In the following chapter, the approach chosen for this thesis will be developed and discussed. The emphasis will be on how to establish scientific theories or models which enable some degree of predictability.

Some epistemological approaches might be better suited for solving particular problems than others, and some approaches are just not as valid as others, in a scientific context. The question of *choosing* the approach is therefore both a question of choosing an approach that is relevant to the problem under consideration in this particular dissertation, and a question of scientific relevance, in general. The question of epistemological approach is a question of making an informed choice.

8.1 Prediction by inference.

Central to epistemological considerations which can lead to predictability are the methods of logical inference, by which knowledge about causal links can be obtained and then validated. Thereby we believe that we can infer something that we do not know from

something that we know e.g. infer how a yet unbuilt piece of architecture will affect us from what we know about how architecture affects us, in general.

At least since Aristotle (384 BC- 322 BC),logical inferences have had the structure of syllogisms, of which a fixed number exists, all with names given to them by scholastic philosophers during the middle ages (Russel 2004,. pp. 188-189). As an example could be mentioned the syllogism “Barbara”, which has the form:

S is M
M is P
Hence, S is P
(Peirce 1878a, vol. 1 p. 186; Russel 2004, p. 189)

Furthermore two types of inferences have traditionally been recognized, namely deduction and induction.

8.2 Deductive reasoning:

Deductive reasoning, of which Barbara is an example, was given its syllogistic form by Aristotle. A deductive syllogism proceeds from a general rule to a particular case, as in this example borrowed from Peirce:

Rule: All the beans in this bag are white
Case: These beans are from this bag
Result: These beans are white
(Peirce 1878a, vol. 1 p. 188)

The advantage of deduction is that it in contrast to the other types of inferences, it is unquestionably logically valid. There are downsides though. First, it follows from this demand that deductive reasoning in this form doesn’t produce any new knowledge in itself, since all knowledge is already represented in the general rule, which is the first premise (Peirce 1878a, vol. 1, p. 187; Russel 2004, p. 191). Secondly, it raises the question of how to establish the rule. Aristotle demanded that for the result to be be correct, the premises – the rule and the case – had to be correct, as well. If, however, we

demand proof that the premises are true, it will lead to an infinite regress, as we will then have to demand that the premises for the proof of our premises are true as well, and so on. Aristotle's solution to this problem, often termed essentialism, was to claim that "basic premises"exist which state the essential nature of things and which therefore do not need any proof. Instead he believed, inspired by Plato that they could be grasped by a kind of intellectual intuition that he imagined we are equipped with (Popper 1945, p.88). Basic premises are also called definitions and definitions therefore become terribly important. The whole activity of science becomes a question of creating a collection of definitions from which everything else can be logically deduced. This in turn means that the whole structure of scientific knowledge in the end comes to rest on intellectual intuition. (Popper 1945, pp 90-91).

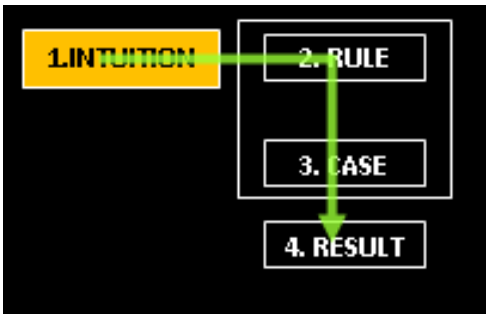

Fig. 8.01. Deduction according to Aristotle. The validity of the result of the syllogism itself rests on 2) the rule and 3) the case, although the validity of the inference as a hole comes to rest on something outside the logical inference, namely 1) intuition.

Aristotle's logic marks the culmination to the creative period of Greek philosophy and was, according to Russel, followed by "2000 years of stagnation" (Russel 2004 p. 157) or as put by Karl Popper: "the degree to which the various sciences have been able to make any progress depended on the degree to which they have been able to get rid of this essentialist method." (Popper 1945, p. 88).

8.3 Inductive reasoning

Inductive reasoning is inferring from a particular case to a general rule, or in syllogistic terms to follow Peirce's example:

Case: These beans are from this bag.
Result: These beans are white.
Rule: All the beans from this bag are white.
(Peirce 1878a, vol. 1 p. 188)

In contrast to deduction, induction refers to experience obtained through the senses, as the syllogistic premises are what is observable. In principle, induction therefore promises to be able to produce new knowledge through observation in the form of new rules. Because induction is founded on the observable, it is associated with empirical science, though it does however not represent the only way to be empirical.

Inductive reasoning has however been controversial since Hume (1711-1776). In his book "An Enquiry concerning Human Understanding", in the chapter called "Skeptical Doubts concerning the Operations of the Understanding" (Hume 2008, pp. 25-29), Hume raised a series of questions which no one seems to have been able to answer in a satisfactory way, to this day, including himself. In summary Hume asked by which rule of logic inference it should be allowed to infer from past observed events to future events and from observed objects to unknown objects (Hume 2008, p.26 – 29) which in both cases presupposes a uniformity of nature. We can therefore not be *rationally* satisfied by inference from observation to instances of which we have no experience, these instances being separated by time or by space, no matter how many previous experiences we have had. Further, Hume pointed out that a rule of induction could not inductively be proven, since induction in itself is a rule, and if it was to be proven by induction, meaning based on observation, it would therefore form a circular argument (Hume 2008, p. 26). However, in the following chapter called "Skeptical Solutions to these Doubts", he tries to save induction by introducing the principle of "custom or habit" that he envisions operates outside the mind and lends validity to the inductive inference (Hume 2008, p. 32).

Inductive inferences from observation are then "….effects of custom, not of reasoning" by which we draw "…from a thousand instances, an inference, which we are not able to draw from one instance" (Hume 2008, p. 32). In the end, the connection of cause and effect is something "that we *feel* in the mind" (Hume 2008; p. 55). In fact, Hume's precise and insightful description of the operation comes surprisingly close to how we today might think intuition works (Hume 2008, p. 32; Damasio 1994 p. 188). Just like Aristotle tried to save deduction by intuition, so does Hume tries to save induction by it. Interestingly, Hume in a short chapter of only two and a half pages develops the idea of 'custom' or 'habit' into the idea of probability (Hume 2008, pp. 41 – 43).

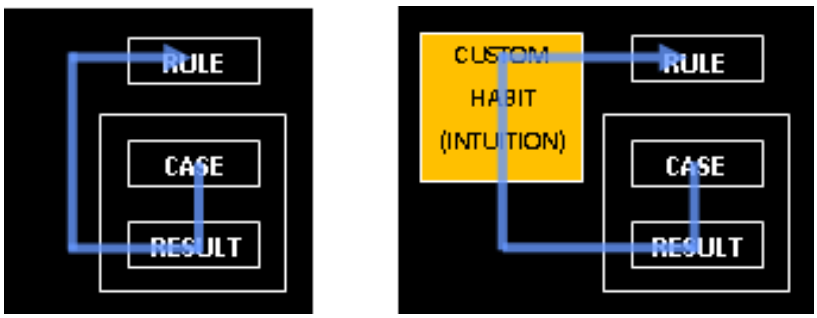

Fig. 8.02. Induction before and after Hume. Hume introduced the principle of 'Custom or Habit' that he envisioned enables inferring rules about causal connections from many repeated instances by a mental capacity outside consciousness. His description resembles a modern understanding of intuition surprisingly well.

It is easy to see how induction might work in a universe that consists only of a bag of beans and one self as in Peirce's example – you can hardly get it wrong. However, in a universe that consists of an almost infinite number of phenomena where it might not be quite clear which ones are directly causally linked and which are causes and which are effects, it becomes evident that it takes an active, cognitive process to link two perceptions together and make a general rule of them. Furthermore, the inference that all the beans in the bag are white presupposes a lot of 'hidden knowledge' – or general rules if one likes – about beans. The knowledge that beans come in a limited number of different colors and that one bean can only have one color keeps you from making the

equal logical inferences that “all beans are white” or “beans become all white when they are removed from their bag”. Thus it has been raised as an argument against Hume that inductive reason only takes place “in the light of a vast store of background information” (Okasha, S. 2001, p. 309), an argument that will lead to infinite regress (Wiley 1975, p. 234; Popper 2002, p.5). Furthermore this demonstrates that the concepts used in the inductive process have to be known in advance, which questions the ability of inductions to produce new knowledge, although founded on observation (Kirkeby 2005, p. 123).

8.4 A way out of the corner

Deduction, though logically valid in itself, in the end will rest on intuition and does not produce any new knowledge anyway. On the other hand,induction is logically invalid for a number of reasons,and at close inspection rests on intuition as well. Nor does it produce new knowledge . How is it possible to proceed from this position?

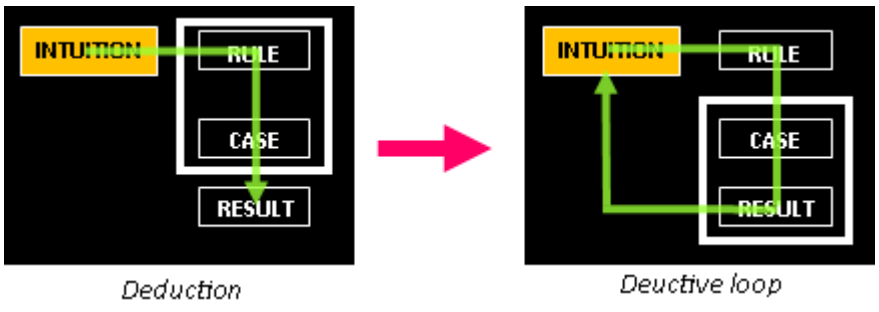

Fig. 8.03. By giving up Aristotle’s demand that the rule had to be correct in order to make the inferences to the result correct and establishing a feedback mechanism, a loop is established for proposing and testing rules. This marks a major shift in interest from absolute truth to the possibility of scientific progress.

Several movements within the philosophy of science seem to revolve around the same idea: simply to give up Aristotle’s demand that the rule, the first premise, as a point of

departure should be true. This means that the process of validation is shifted to the case and the result, and otherwise leaves the Aristotelian scheme unaltered. As the rule-prediction of the result as a point of departure probably will not be accurate, improved accuracy can then be established by following a feedback process whereby the rule is corrected towards improved ability to predict the result.

The emphasis is then on generating useful rules rather than finding absolute truth; of learning rather than knowing.

The dilemma indicated by this is that we cannot possibly have absolute truth and generate rules at the same time. You could say that the infinite regress of Aristotelian logic is shifted to infinite progress towards a truth that we might come ever closer, yet never reach. This leads us to realize that this change rather represents a shift of interest than a break away from "2000 years of ignorance" of Aristotelian logic.

Up until now deduction has been associated with logical operations of the mind, which is rationalism. Induction on the other hand has been associated with observation by means of the senses, which is empiricism. By the operation described deduction is made empirical, as well. The new ‘loop of inference’ that has been created, though it combines rationalism and empiricism, will here be termed “the deductive loop” because it starts with a rule just like ‘classical deduction’ . The reason why it has to, is that the rule will contain a general assertion independent of time and space about all objects or events of a certain class, and thereby escape Hume’s argument against induction, at least in the first instance. It does not presuppose uniformity of nature; it only proposes it to be tested in the instances it describes.

The deductive loop can also be seen simply as an overlay of deduction and induction (fig. 8.4) which gives rise to a long standing confusion of wording.

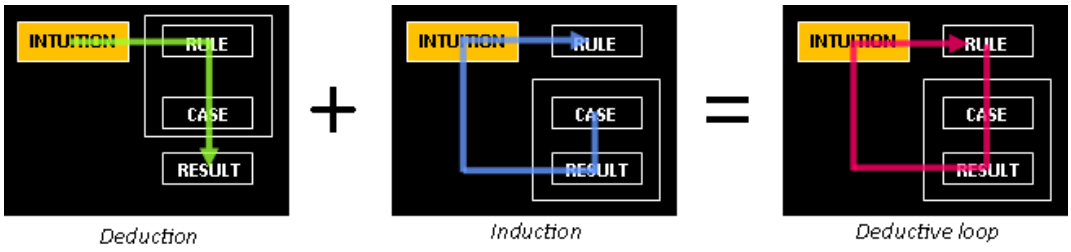

Fig. 8.04. The deductive loop seen as a hybrid inference consisting of an overlay of deduction and induction.

As an example of the mish mash of nomenclature created by this hybrid inference, Peirce defines *induction* as follows: “Induction consists in STARTING FROM A THEORY, DEDUCING from it predictions of phenomena, and observing those phenomena in order to see *how closely* they agree with the theory.” (Peirce 1903, vol. 2 p. 216; my capitals). While Karl Popper wrote: “The belief that we do use induction is simply a mistake. It is a kind of optical illusion. What we do use is a method of trial and the elimination of error; however misleadingly this method may look like induction, its logical structure, if we examine it closely, totally differs from that of induction.” (Popper 1953; 1974, p. 104), basically describing the very same process.

8.5 Different epistemological attitudes to the deductive loop

As mentioned before, the idea has been put forward several times in history more or less independently under different names and with slightly different results, though the core idea seems to be the same.

8.5.01 Socrates

In a dialogue in Plato’s work Theaetetus, in which Socrates in a dialogue on behalf of Protagoras suggests that “while one judgment cannot be *truer* than another, it can be *better*, in the sense of having better consequences.”. However, the argument fell on the question of how to determine which one is the better one, that is to say how to make the

subjective opinion of which one is best into objective knowledge, because "…we cannot escape the conclusion that a wise man is a better measure of things than a fool" (Russel 2004, p. 150).

8.5.02 Hermeneutics

In hermeneutics', original a method for interpreting literature that dates back to the late 18th century that has developed into a method widely used within the humanities in general. Within Hermeneutics, the loop is described as: "In the interpretation of a text you must always take a hypothetical-deductive approach. You submit a hypothesis about the text and verify it by seeing how its consequences fit with various details in the text."[1] (Paahus 2008, p. 148). The idea of criticizing and adjusting a rule/hypothesis by the results it produces, and the constant alternation between the overall idea of the proposed hypothesis and the detail of the case is called the hermeneutic circle. It should be noted that the method could just as well have been applied to the analysis of a work of architecture, for example.

8.5.03 Pragmatism and instrumentalism

Pragmatism as a movement within philosophy came into being in America in the second half of the 19th century, with Charles Sanders Peirce (1839 - 1914), William James (1842-1910) and John Dewey (1859 – 1952) as some of its most prominent members. Peirce, who is considered the founder of pragmatism, formulated what he calls "the maxim of Pragmatism" as follows: "Consider what effects that might conceivably have practical bearings we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object" (Peirce 1903, vol. 2 p. 218). In other words, it is the effect in terms of "practical bearings" of an object and not its 'essence' that matters. Consequently, inferences bring about the effect of rules, and the effect that comes to determine their truth value. As mentioned, Peirce described the deductive loop,

[1]Original Danish text: "I fortolkning af en tekst må man altid gå hypotetisk-deduktivt til værks. Man fremsætter en hypotese om teksten og efterprøver den ved at se, hvordan dens konsekvenser passer med de forskellige detaljer i teksten."

which he termed induction, as a process where a prediction is deduced from a theory and validated by inductive testing by comparing the result to the prediction. (Peirce 1903, vol. 2 p. 216). It should be noted that it is precisely this equation between the truth value of a rule and its effect that makes this comparison between a prediction of a rule and its impact possible. The only element of the deductive loop that is not present in Peirce's conception of induction is 'intuition'.

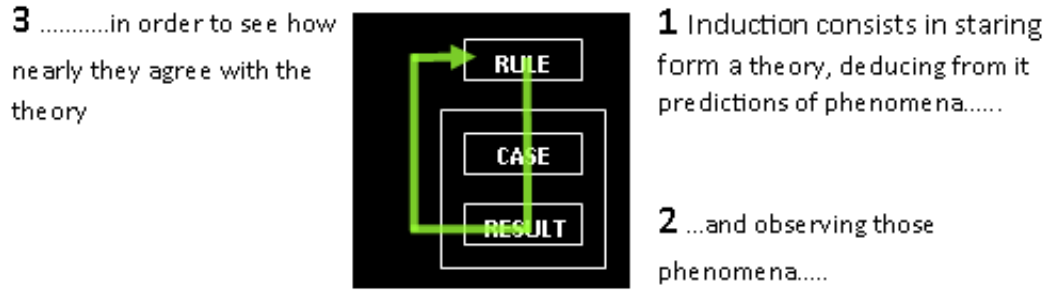

Fig 8.05. Peirce' s version of the loop, which he calls 'induction' although it starts with deduction. The only phase not represented is 'intuition' which makes it difficult to account for how the rule is generated. (Peirce 1903, vol. 2, p. 216)

The lack of the intuitive phase however leads Peirce into trouble when it comes to explaining how the theory/rule is generated. This leads him to introduce what he saw as a new form of inference, called abduction. As we have seen from Aristotle and Hume, neither deduction nor induction is capable of producing new knowledge until "intuition" is introduced. However, intuition is bound to undermine the validity of the inferences if it's directly or indirectly part of the logical inference itself – like in Aristotle where it must be capable of producing first premises in the form of 'basic premises', or in Hume where it becomes the inference itself. Peirce solves the problem by introducing a type of inference called abduction, where intuition is not part of or forms the basis of the inference, but is evaluated by it. By this, the capability of 'intuition' to suggest new knowledge and the logical integrity of the inference are preserved. Peirce defines abduction as follows:

"Abduction is the process of forming an explanatory hypothesis. It is the only logical operation which introduces any new idea; for induction does nothing but determine a value and deduction merely evolves the necessary consequences of a pure hypothesis.

Deduction proves that something *must be*, Induction shows that something *actually is* operative, Abduction merely suggests that something *may be*.

Its only justification is that from suggestion deduction can draw a prediction which can be tested by induction and that, if we are ever to learn anything or to understand phenomena at all, it must be by abduction that this is brought about"
(Peirce 1903, vol. 2 p. 216).

According to Peirce abductive reasoning has the form:

- The surprising fact, *C*, is observed
- But if *A* were true, *C* would be a matter of course.
- Hence, there is reason to suspect that *A* is true

Quite in line with the suggestion Socrates dismissed, this is in fact finding the hypothesis which is best for explaining the observed surprising fact, as it implies the valuation of competing possible hypotheses on the grounds of their consequences. In fact, the 'surprising fact C' has to be surprising compared to what was anticipated, and the anticipation has to refer to some prediction by a previous hypothesis, so the idea of abduction is basically deductionist and pre-empts fallibilism, as the inference could have been written:

- Instead of the anticipated outcome C_1 predicted by the hypothesis A_1, the surprising fact C_2 is observed.
- But if the competing hypothesis A_2 were true instead of A_1, C_2 would be a matter of course.
- Hence, there is reason to suspect that A2 is a better hypothesis than A1.

The creative process of ‘intuition’ is absolutely central to abduction and is reintroduced into the deductive-inductive circle under the name of the abductive moment, as Peirce writes: “The abductive suggestion comes to us like a flash. It is an act of insight, although of extremely fallible insight.” (Peirce 1903; vol. 2, p. 227).

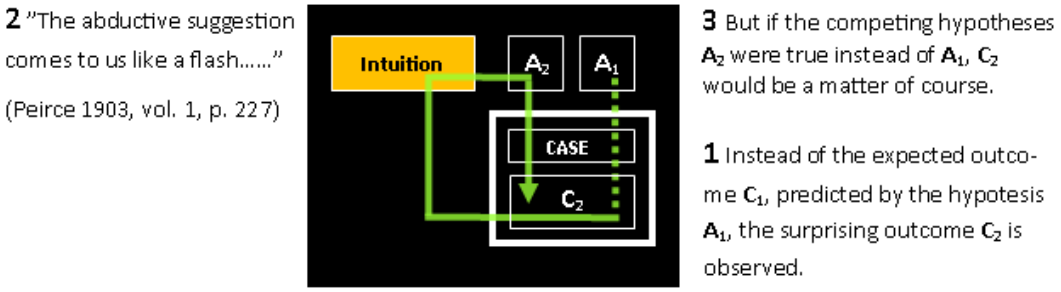

Fig. 8.06. Peirce’s abductive reasoning.

In fact, Peirce by abduction suggests the use of a deductive loop as a means to test hypotheses: “I mean to extend it to every case in which, having ascertained by deduction that a theory would lead us to anticipate under certain circumstances phenomena contrary to what we should expect if the theory were *not* true, we examine the cases of that sort to see how far those predictions are borne out” (Peirce 1903; vol. 2, p. 234). Thus, both Peirce and James turn towards the idea of truth as relative entity, as James writes “Truth lives, in fact, for the most part on a credit system. Our thought and beliefs ‘pass’, so long as nothing challenges them, just as bank-notes pass so long as nobody refuses them” (James 1907, p. 91). For Peirce this leads to the recognition that the negative result is actually the only one which gives some certainty about the validity of a theory and is capable of generating progress: “If nature replies “No!” the experimenter has gained an important piece of knowledge. If nature says “Yes,” the experimenter’s ideas remain just as they were, only somewhat more deeply engrained.” (Peirce 1903, vol. 2 p. 215). This, as William James remarks, makes some demands for an idea to be called scientific: “True ideas are those we can assimilate, validate, corroborate and verify. False ideas are those that we cannot” (James 1909, p. 88). On the whole, the pragmatist conception of theories

means that “Theories thus become instruments, not answers to enigmas, in which we can rest” (James 1907, p.28).

8.5.04 Fallibilism

In the 20th century, Karl Popper has probably been the single philosopher most associated with the idea, and his influence on the theory of science has been profound. To a large extent, his ideas are aligned with those of Peirce and the pragmatist though on some issues taken to a further level of logic consequence.

Popper suggests that as it is apparently problematic to look for sources of truth as there is no criterion of truth available, we should instead look for errors in our conception of truth, thus the process of producing knowledge becomes an activity of detecting and eliminating error (Popper 1960, p. 52 - 55). Popper in fact suggests what Socrates rejected that “we can, in most cases, determine with great confidence which of any two theories is the better one. We can therefore know that we are making progress….”.(Popper 1945, p. 90). The consequence is that knowledge becomes a dynamic, rather than an absolute phenomenon, as Popper states it: “What we should do, I suggest, is to give up the idea of ultimate sources of knowledge, and admit that all human knowledge is human: that it is mixed with our errors, our prejudices, our dreams, and our hopes: that all we can do is to grope for truth even though it be beyond our reach” (Popper 1960, p. 57) with the consequence “that the acceptance by science of a law or a theory is tentative only; which is to say that all laws and theories are conjectures, or tentative hypotheses…” (Popper 1953, 1974, p. 102).

This shift of attention from the truth of a theory to the errors which it might hold is the basis of Popper's theory about falsification. As stated by Popper: “So long as a theory stands up to the severest tests we can design, it is accepted; if it does not, it is rejected. But it is never inferred, in any sense, from the empirical evidence. There is neither a psychological nor a logical induction. *Only the falsity of the theory can be inferred from empirical evidence, and this inference is a purely deductive one*.” (Popper 1953, 1974, p. 102). Thus we see, that Popper's idea of deductivism aligns perfectly with the process Peirce terms induction. Just as in Peirce’s inductivism, empirical observation is crucial

and does *not* produce the theory – it is used for testing only, and importantly, only *after* the hypothesis has been advanced (Popper 1934a, p. 133). Thus both Popper and Peirce are in direct opposition to the so called inductive-deductive method (Knudsen 2005, p. 87). On the contrary, the methodology they describe is deductive-inductive.

Thus, it becomes an indispensable demand for a theory that it is falsifiable, even more than it is justifiable, and "that a theory is scientific to the degree to which it is testable" (Popper 1974, p. 123). It follows from this that theories with a low probability or high risk of being falsified also have the greatest potential for facilitating scientific progress (Popper 1960, pp.174 – 176). As a consequence of the demand that it must be possible to determine whether a theory is confirmed or falsified "A theory is to be called 'empirical' or 'falsifiable' if it divides the class of all possible basic statements unambiguously into the following two non-empty subclasses. First, the class of all those basic statements with which it is inconsistent (or which it rules out, or prohibits): we call this the class of the potential falsifiers of the theory; and secondly, the class of those basic statements which it does not contradict: a theory is falsifiable if the class of its potential falsifiers is not empty". (Popper 1934b, p.150). This means that in order to be falsifiable, the theory must divide all possible answers or predictions of the phenomena it tries to describe into those statements which falsify it, and those which confirm it, in order to fulfill the criteria of falsification.

As an example it can be seen, that if the initial research question is divided according to whether architecture can affect health into to sub-classes (*fig. 8.07*), a single result in the class of "architecture can affect health" will falsify the statement "Architecture cannot affect health", and give us some confidence in the predictive power of the model that produced the result. Unfortunately the opposite cannot be said. As the inquiry will be directed at testing for predicting how architecture can affect health, a negative result will just falsify this particular model and not the entire class "Architecture can affect health" as it will not rule out that some other model will be capable of producing a positive result.

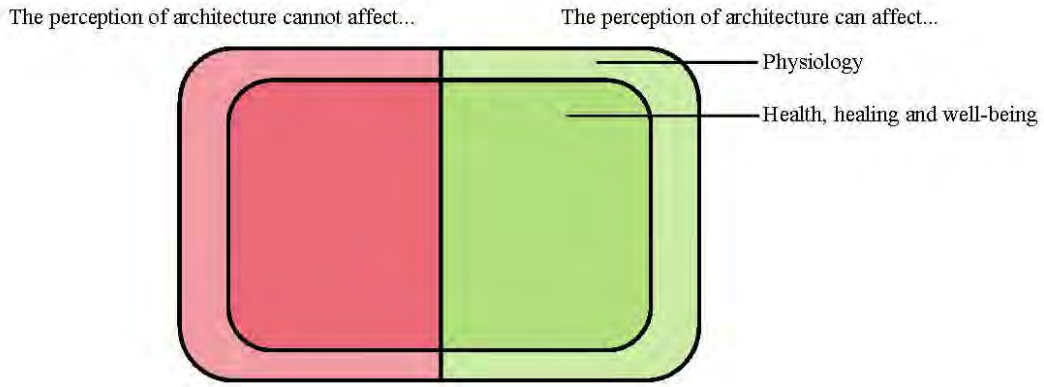

Fig 8.07. To fulfill the requirement of dividing the class of all possible basic statements unambiguously into two non-empty subclasses of falsifying or confirming statements, the initiating research question can now be subdivided into the following groups of statements.

8.6 The relationship between theory and hypotheses

Popper does not use the words "hypothesis" and "theory" consistently through his long authorship. Sometimes they are synonymous, where hypothesis means a theory at a yet unconfirmed stage (Popper 1945, p. 90). In other cases, he describes a hierarchical relationship where he distinguishes between the theory and “low-level empirical hypothesis”, also called a “falsifying hypothesis” (Popper 1934c, p. 150). In the context of this thesis the perception of a hierarchical relationship will be used.

At least in the social sciences, with which a positive science of architecture may align, hypothesis driven research has, according to Kenneth R. Thomson, failed to develop theories from which predictions in general can be derived. Instead, the hypothesis developed within these sciences has shown to relate to “very specific questions relating to specific observations” (Thompson 2006, p. 14). The dilemma is that if a hypothesis should be tested in order to falsify it, it must relate to a very specific question in order to get the very specific results of a test that is necessary for a potential falsification – in

other words, the ‘specificness’ stems from the demands of testability. But if a hypothesis only contains statements of very specific cases, it becomes problematic to deduce predictions of the results of other cases from it. In fact, by just confirming expected outcomes of specific cases we run the risk of compromising its ability of predicting about the outcome of any case within the class of phenomena it is intended to describe. The attempted solution to the problem has been to attempt to construct theories from a number of tested hypotheses, but this implies an inductive process and has proven unsuccessful (Thompson 2006, p. 14 & pp. 19-20). Among the problems of this method is that it should be demanded of a theory that it contains predictions which are not obvious and not otherwise obtainable, if it is to constitute scientific progress (Thompson 2006, p. 16).

In a hierarchical system, the theory must contain general statements from which predictions about a certain class of events or objects can be deduced, so that predictions in general can be deduced from it. Hypotheses linking “very specific questions” to the predictions of very “specific observations” can then be derived from the theory. Where theory itself is not easily testable because of its general character, the hypotheses are because they deal with specific instances of the phenomena described by the theory , predicting a specific outcome in a specific case, and thereby they obtain falsifiability.

This means that the role of the theory and the role of the hypothesis are very different, although they are closely tied together in one interdependent system. Groat and Wang describe the theory, which in their terminology covers both the theory and the hypothesis, as having a “Janus position” (Groat & Wang 2002, p. 87) as “it draws from philosophical underpinnings for its own sense of legitimacy and coherence. On the other hand, it posits specific explanations about something in nature or the social/cultural world and makes its claims amenable to testing and analysis by means of research”. However, in this context the position of the theory/hypothesis complex is a Janus position with at least three faces. The first one addresses whatever generates the theory. This has up until now been represented by the feed-back mechanism and the “intuition”, but will be treated in greater detail below. The second one is that within this framework of the need for a positive science of architecture, the theory has to communicate with the artistic and the normative level. The third one is that the theory has to gain the status of knowledge by demonstrating that it refers to an objective reality, for example through empirical tests. In

the model below (*fig. 8.08* it is demonstrated how the theory is generated and through the deductive loop, validated in terms of the derivation of falsifying hypotheses. Further it is shown how ,because of the general character of the theory, the artistic and normative levels can gain knowledge about specific cases by using a classical form of deduction.

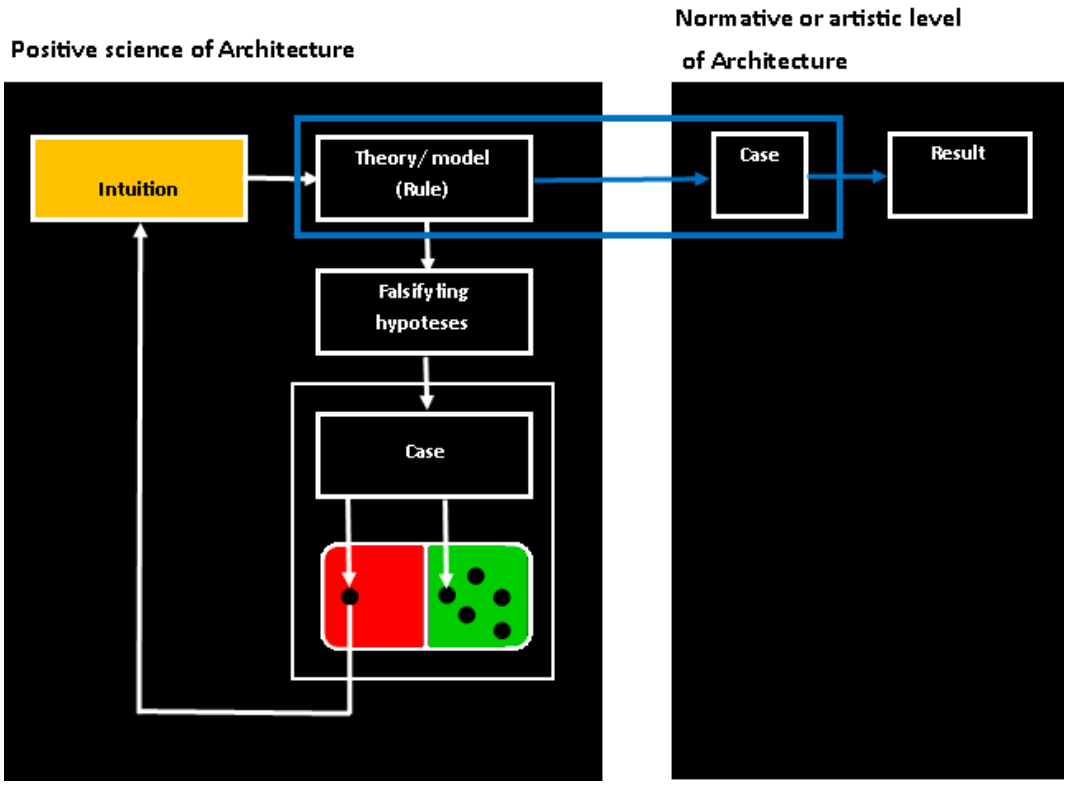

Fig. 8.08. The "three faced Janus position" of the theory; its relation to intuition, to the falsifying hypotheses and the validation process, and its communication with the normative and artistic level

The more a theory survives attempts to falsify it by testing the hypothesis, the more we may trust predictions derived from it. Because of the general character of the theory, the normative and artistic level is able to deduce predictions of not previously tested specific

cases from it. Another consequence is that a hypothesis, and thereby the theory it corresponds to, can be falsified even by a single observation (Popper 1953, 1974, p. 110), provided that this observation is reproducible. Conversely, many results confirming the theory do not prove it; they just give us more confidence in its predictions. As Popper writes: “We shall take it as falsified only if we discover a reproducible effect which refutes the theory. In other words, we only accept the falsification if a low-level empirical hypothesis which describes such an effect is proposed and corroborated. This kind of hypothesis may be called a falsifying hypothesis.” (Popper 1934c, p. 150). As the theory is more and more thoruohgly tested and corrected, it may gain in content and precission, and as it accumulates knowledge, the classes it describes may be more and more precisely defined.

8.6.01 The creation of the theory

Up until now the focus has been on how a rule/theory is validated. However, way back, beginning with Aristotle, the crucial problem has been how the rule/theory is generated in the first place. We have seen that none of the examined inferences could produce new knowledge until some kind of creative element was introduced, covering synonymous concepts like Aristotle’s “intuition”, Hume’s “habit” or “custom” as well as Peirce's “abductive moment”. As a theory clearly cannot be created and validated by the same process, the effort in the described development has been to isolate the validation process from the creative process of generating the theory, by making validation an independent empirical process. Thus we have two very different processes; the one which creates the theory, basically the one that through its propositions creates knowledge, and the one which validates it, that is ‘confirms’ it or falsifies it (Popper 1934a, p. 134).

Constructing the theories or hypotheses is a “creative act of inspiration, intuition;….The process must be discussed in psychological, not logical, categories” (Friedmann 1953, p. 43); it is “akin to explanatory story telling, to myth making and poetic imagination” (Popper 1973, p. 83). It needs not have any logical, valid structure, because it does not lend any validity to the hypotheses, or in Popper’s words: “…..there is no such thing as a logical method of having new ideas, or a logical reconstruction of this process. My view may be expressed by saying that every discovery contains ‘an irrational element’, or ‘a creative intuition’, in Bergson’s sense.” (Popper 1934a, p. 134). Popper goes so far as to

claim that the process leading to the construction of the hypotheses is of no interest to others; it might not even be fully known to those who constructed it (Popper 1960, p.53).

It is of course correct that the possible logical validity of whatever led to the proposition of the hypothesis has nothing to do at all with the validity of the theory itself – otherwise it would compromise the validation process. Despite this, the process and the reflections that have led to the theory in so far as they are consciously recognized, might be of great interest to other researchers for several reasons. First of all, as mentioned, the value of a hypothesis lies in its falsifiability. To know the reflections that led to the proposition of a theory or a model might be of great help to those who might want to falsify it. Secondly, choices have inevitably been made along the way – other researchers might not agree with these choices and want to investigate some of the possibilities which have been opted out. Thirdly, obvious ideas might have been overlooked or other researchers with additional knowledge from other fields or with other methodological approaches might be able to see other possibilities. For these reasons and for the sake of the critical debate, a researcher must have an obligation to present the reasons for what he proposes for those who might be interested. The only thing that these descriptions of the process *cannot* be used for is criticizing the theory or the hypotheses – it gains its validity from the deductive/empirical validation process alone, and criticism concerning validity must be directed at this. It is important to distinguish between the origins and the validity of knowledge. Fourthly, although Popper stresses the intuitive creative aspect he admits that "Knowledge cannot start from nothing – from a tabula rasa – not yet from observation. The advance of knowledge consists, mainly, in the modification of earlier knowledge" (Popper 1960, p. 55).

In other words, in order to advance the scientific knowledge base, the theory must take the current state of knowledge as its point of departure and be able to contribute to this knowledge base itself. Beside the theory's ability to communicate with the normative and artistic level, we can now identify a third very important demand, the ability to contribute to the total volume of scientific knowledge. This could be termed the theory's scientific contribution.

It is now possible to identify three stages of the generation of the theory, all governed by the research question under investigation. The first step will be to identify the existing knowledge within the field in terms of a literature review (Groat & Wang 2002, p. 45 – 52). The next step will be to generate new ideas on the basis of the existing knowledge – this will be the phase of 'intuition'. The third phase will be to explain and argue the formulation of the theory – the explanatory phase that Popper termed "myth making". For the sake of communicability, these three phases should preferably be systematically represented in that order. However, although a certain systematic approach must be required during the process itself, it should not be underestimated that it is a creative, dynamic process (Groat & Wang 2002, p. 48). It will be subject to much iteration and to moments of doubt and perplexity as well as joy and sudden insight, as creative processes always are. Thus the literature review phase will probably spark new insights and ideas that possibly will alter the research question and definitely the course of the explanatory "myth making" phase. The explanatory phase will most likely require additional literature review, possibly including other fields of knowledge and hopefully spark new ideas and so on. While the validation process must call for rigorous method and precision throughout, there will be a marked difference in how the process of generating the theory is communicated and how it is performed.

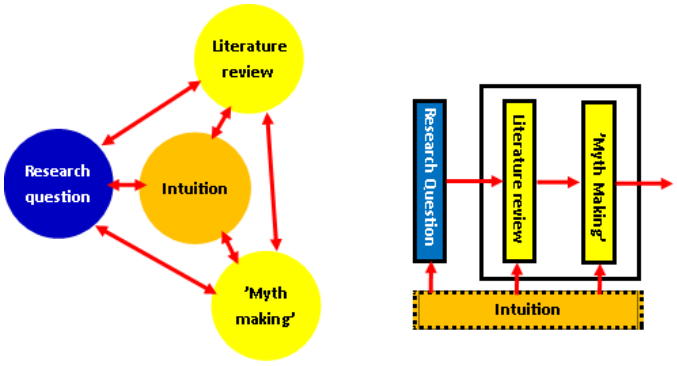

Fig. 8.09. How the process of generating the theory is performed and how it could be communicated in a systematic form. In its communicable form, intuition might only be implicitly present.

8.7 Objectivity

The creative process of creating the theory is subjective, meaning that the theory, no matter how well argued, is the opinion of those who put it forward. The whole process since Aristotle can be seen as an attempt to strictly separate the subjective basically non-rational, creative process of creating theories from the rational process of validating them. In order to become scientific knowledge, the theory must pass from a state of subjective opinion to a state of objective knowledge. The transition from the quest for absolute truth to a concept that rather seeks dynamic knowledge raises the question of how and who can decide what is objective, as already Socrates noted. Peirce answers this question by what could be called an intersubjective answer: “They (the scientists) may at first obtain different results but, as each perfects his method and his processes, the results will move steadily together toward a destined center. So with all scientific research…….The opinion which is fated to be ultimately agreed to by all who investigate, is what we mean by truth, and the object represented in this opinion is the real…….and the opinion which would finally result from investigation does not depend on how anybody may actually think. But the reality of that which is real does depend on the real fact that investigation is destined to lead, at last, if continued long enough, to a belief in it” (Peirce 1878; vol. 1, pp. 138 - 139). In other words, you cannot vote on what objective reality is, and consequently the debate among the individual subjects, being it “wise men” or “fools”, will converge towards objective truth, as long as it is guided by results from an investigation that “does not depend on how anybody may actually think” but on its empirical relation to the supposed objective reality under investigation. This means that “only such statements may be introduced into science as are intersubjectively testable” (Popper 1934, p. 142), meaning that observations that serve as critical arguments must be understandable to everybody, and if it is observations in the form of experiments, they must be reproducible by everybody. (Popper 2002, p. 22).

8.8 Predictability

The point of departure was to investigate whether predictability could be obtained. As it has become apparent, scientific models or theory only represent tentative knowledge, so it

has become clear that predictability is only tentative as well, and that we can only say that we can predict something to the best of our current knowledge. In principle, our theories are certainly all wrong and will sooner or later be replaced by better ones. They only represent the best and most precise knowledge about the world and/or ability to predict it available at the moment, and only if they via a scientific process can be made to have a reasonably precise degree of predictive power, science has something to offer society in practice. This is very important to communicate to the users, in architecture the normative and artistic level, as the popular idea of scientific knowledge is still often that of absolute truth. A difference in perception will create mistrust and undermine the cooperation between the different levels, at the expense of the benefits society can derive from research.

8.9 Schematic representation of a research project

An overview of the different elements of a research project has now been produced. It consists of two phases; the first phase generates the theory but has nothing to do with validation, the second phase validates the theory but has nothing to do with its creation (see fig. 8.10). According to Groat and Wang (2002 p. 10) the validating phase can be divided into research strategy and research tactics (Groat and Wang 2002 p. 10). Strategy is the overall plan for its validation, in this case the skillful formulation of potential falsifying hypotheses, where the tactics stand for detailed test of it. It has been demonstrated, that fallacies in the theory-creating phase have no influence on the validity of the theory, as such. The theory legitimacy as knowledge is due to the validation process and consequently what can question the theory (or its falsification) can be isolated to either strategic or tactical errors. That is, if the falsifying hypothesis is not correctly derived from the theory (strategic error) or it is not properly tested (tactical error).

To argue that a single or a limited set of known methods should define science would imply superior knowledge of all thinkable theoretical approaches and of all problems that science might face now and in the future – such an insight seems impossible. It therefore seems unacceptable to talk about *the* scientific method; rather it is appropriate to discuss whether a method is a scientific method. Quite what a scientific method is and what it is

not should be determined on the grounds of criteria for the knowledge it produces. The criteria for anything to be called science could be that it is capable of producing new, objective knowledge. To evaluate the proposed method by these criteria, it must be noted first that it is capable of producing new knowledge, because it is capable of proposing new theories through the creative process. Secondly that it through the validation process is capable of turning the proposed theories into objective knowledge, by systematically relating them to an objective reality to the degree that it might exist. Furthermore, the aim is to find a method that could deal with predictability. It must be pointed out that this model gives a fairly good picture of what is meant by “predictability” and with which degree of confidence it is at all possible to say anything about the future. It is capable of producing theories that constitute statements about the world which, in as much as they are in accordance with an objective reality, will make predictability possible.

It should be noted that the described process is neither exclusively qualitative nor quantitative, but could just as well be applied to statistics as hermeneutics. In qualitative studies, a single observation that can be shared can lead to change in the proposed theory, for example about the conception of an urban area. When it is not possible to falsify the hypothesis by one single observation, quantitative methods might be used. In quantitative studies the two classes of the falsifying hypotheses would align to the hypotheses and null-hypothesis in statistics, and tactical errors would be associated with type-1 errors (to reject a true null hypothesis that is, fail to falsify the hypothesis that should have been) or type-2 errors (fail to reject a false null hypothesis). Those statistics are about determining which of two rival hypotheses is the most probable, and the statistical significance means assessing the probability that the null hypothesis is true.

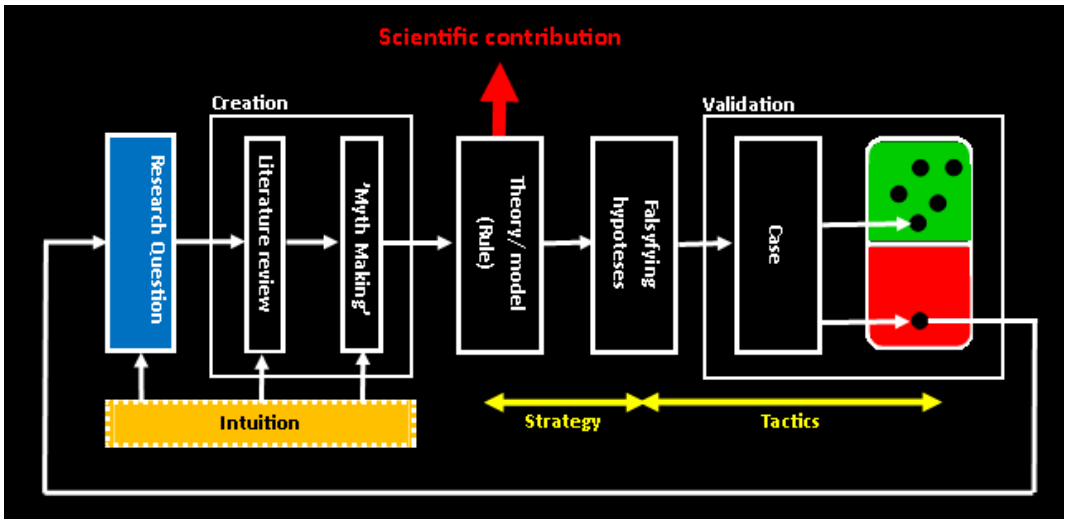

Fig. 8.10. Schematic representation of the structure of a research project as it could be structured according to the discussion in this chapter.

9

State of the art

As it has been indicated, the idea that architecture can influences health is not new. In this chapter, state-of-the-art concerning existing knowledge as to whether the perception of architecture can affect health will be reviewed. This will include existing evidence as well as existing theories and methods.

In the search for existing knowledge regarding whether architecture can influence health, it is at first important that the review is done in accordance with the criteria that ensure its relevance in relation to the initiating research questions:

- *Can the perception of architecture affect health?*
- *Can the perception of architecture affect us physiologically?*

Here perception is understood as “the organization, identification, and interpretation of sensory information in order to represent and understand the environment” (Schater, 2011) and architecture is understood as the built environment, that is to say not landscape, not cities and not design items.

By systematically relating the reviewed knowledge to the initiating research questions, the relevance of the resulting pool of knowledge in terms of its content as well as its structure ensures that a necessary and relevant scientific contribution can be identified. As

the key-words of the initiating research question in the broadest sense are perception, architecture and physiology, relevant knowledge might be related to the following criteria:

A. It must concern *architecture*.

B. It must include the *perception* of architecture.

C. The perception of architecture must initiate a physiological response related to health.

9.1 "Healing Architecture" ("Helende Arkitektur")

"Helende Arkitektur" (Frandsen et al. 2009) was a state-of-the-art research project conducted by a research group within Aalborg University with the purpose of collecting existing scientific evidence about hospital design. The project was carried out by a group consisting of researchers, of which the author of this thesis was one, from SBI (The Danish Building Research Institute) and Institute of Architecture and Design from Aalborg University. The literature search was conducted within databases such as The Danish Research Database [2], Library.dk[3], Libris.se, Hospitalplan.no[4], Ask.bibsys.no, Healthdesign.org and Pubmed. The result was a database on 925 references, which was evaluated on the criteria that they had to 1) have been published in a peer reviewed scientific journal 2) be a primary source 3) represent knowledge based on evidence 4) represent research in the relation between the body, the senses, hygiene or safety on the one hand, and architecture on the other hand. The literature search and the size of the resulting database relative to the field architecture and health make it probably the most

[2]Den danske forskningsdatabase

[3]Bibliotek.dk

[4]Sykehusplan.no

comprehensive review made within the field. After the evaluative process 122 references were selected for presentation in the report, and 45 references of more peripheral relevance were recommended as further reading. This review represents thus a thorough overview of the existing research.

When the remaining 122 key-references are sorted according to the criteria of this research project A, B and C, they can be categorized into four groups according to their relation to the criteria.

9.1.01 References which do not fulfill either criteria A (architecture), B (perception) or C (physiological effect).

A total of 61 references are concerned with functional matters related to staff, discussions concerning possible advantages of having single bed rooms, efficiency of way-finding systems and food distribution systems, hygiene, safety and avoidance of accidents etc. Though neither stress nor any other physiological or emotional effects are mentioned as a result of insufficient way-finding in the studies referred to in “Healing Architecture”, it should be mentioned that Ulrich et al. (2010) in a review mention stress as an effect of inefficient way-finding systems. However, this appears to be on a purely speculative basis, though it has not been possible to track all references mentioned by Ulrich et al. A minor group is before-and-after studies of different types of wards with the purpose of measuring whether progress has been made. In these types of studies it is however often difficult to point out exactly what is the cause of e.g. improved staff and patient satisfaction.

9.1.02 References which do not fulfill A(architecture), but fulfill B (perception) and C (physiological effect).

A total of 27 references have to do with gardens or views to nature; these are excluded due to the criteria that limit this investigation to the built environment. However, there are some very interesting results within this group. Without doubt the most important is the study by Roger Ulrich from 1984, in which patients admitted to wards that only differed with respect to the view were compared. Half of the patient rooms had a view to “a small stand of deciduous trees” and the other half to a brown brick wall. All patients had

undergone the same operation (gall bladder surgery), were cared for by the same staff and were randomly assigned to the patient rooms. The survey was conducted by studying patient records from a period of 9 years (1972 to 1981) between May 1st and October 20th, when the trees had foliage. It was found that there was a significant difference in postoperative hospital stays (7.96 days for the tree group and 8.70 for the wall group), negative evaluative comments from nurses, use of moderate and strong analgesic doses and postsurgical complications. The fact that it was actually just a small stand of trees (Ulrich, 1984) and not as it is often referred "nature", implying a more spectacular scene (Hamilton, 2003), underlines the substantiality and power of the effect. It is clear that a marked physiological effect is indeed relevant, as far as healing is concerned. However, in the context of this inquiry, the study suffers from several drawbacks 1) The studies focus on nature and not on architecture. As the architecture represented by the patient rooms is deliberately held as a constant, no information regarding the architecture can be drawn from the survey 2) The hypotheses tested are concerned with the expected causality based on assumptions and are not rooted in any theory of the underlying physiological mechanism, which makes it difficult to generalize from it. Indeed, Ulrich notes that "The conclusions cannot be extended to all built views, nor to other patient groups". However, in a later study, not included in "Helende Arkitektur" (Frandsen et al. 2009), Ulrich et al. (1991) investigate the restorative effect following stress by natural versus urban scenes, including physiological measures. Subjects are first shown a stressful videotape and subsequently videotapes with either one of two different urban scenes or a natural scene. Skin conductance, changes in pulse transit time, changes in muscle tension and changes in heart period are measured during the restorative period, indicating for all measures that natural scenes by far give the most restorative effect. If any parallel to the 1984 study of the effect of views to trees versus a brick wall can be made, it might indicate that physiological stress could be part of the underlying mechanism responsible for the healing effect observed in the 1984 study. In a review (Ulrich et al. 2004) it is recommended to reduce patient stress, but only by reducing environmental factors which cannot fulfill the criteria of perception such as amount of noise or the light, or by providing views to nature which cannot be categorized as architecture.

Another interesting group among those references is one which uses video tapes of

nature scenes as a distractor to dampen pain . Subjects who participate in a study on pain were either shown a video of a natural scenery or nothing. Those who saw the video had a significantly higher pain threshold than those who did not (Tse, 2002). Some patients who underwent Flexible Bronchoscophy, an examination of the respiratory tract using a fiber optical device, were, as a supplement to the standard mild,sedative drugs, offered a picture of a natural scene to look at, and headphones with natural sounds. There was a significant difference in the experience of pain compared to a control group, but no difference in anxiety (Diette 2003).

9.1.03 References which fulfill A (architecture) and C (physiological effect), but do not fulfill B (perception).

This group includes a total of 29 references which deal with the effect of the amount of light, sound or temperature. The physiological effects include depression and sleep disorders, but also length of hospital stays and mortality. However, the *amount* of e.g. light can hardly be said to fulfill the demand of representing an organization, identification, and interpretation of sensory information or a representation and understanding of the environment, and can therefore not meet the demand of being a perception of the environment. The isolated information that e.g. the amount of daylight was so-and-so many lux do not allow for organizing this sense data into a representation. Furthermore, the physical framework e.g. the patient room is in general kept as a constant, which gives very little information about the architecture, as mentioned above . No theory of the underlying physiological mechanisms is presented, making it problematic to generalize from the results. As an example could be mentioned a study by Beauchemin and Hays (1998) on the effect of the amount of daylight on the length of hospitalization and mortality among patients who were admitted directly to a cardiac intensive care unit with a first attack of myocardial infarction. The wards were identical except with respect to their orientation relative to the compass. The results indicated that there was a significant difference in the length of hospital stays for women, and a significant difference in mortality in both genders depending on whether they had been admitted to sunlit or dull rooms, as mortality in the south-facing rooms was 7.2% versus 11.6% in the north-facing. However, the authors write in their conclusion that “We did not then and do not now have a coherent theoretical underpinning for our findings, and

can only refer to some well-known observations." (Beauchemin and Hays,1998). It is clear that the great value of studies like this is first and foremost to have discovered that some powerful mechanism is at work, by which the environment can influence even mortality in a profound way. It is however difficult to generalize, as long as the underlying physiological mechanism is not known. Has this for example to do with the heart's special status relative to the autonomic nervous system? This means that the effect cannot be generalized to include other serious medical conditions; or could the effect of the sunlight for example be related to an interplay with other environmental factors, for example to dampen stress – which would work on the autonomous nervous system – caused by for example a noisy environment, meaning that the effect of the sunlight would be diminished if a possible noise problem or other kinds of stress problems were solved. Thus it is not possible to generalize from this study neither to other environments nor to other medical conditions. These and numerous other more complex possible explanations make it evident that it is necessary to build theories that include the mechanisms at work, if it should be possible to generalize to other instances.

9.1.04 References which fulfill A (architecture) and B (perception) but do not fulfill C (physiological effect).

A small group of 5 studies actually has architectural space as the variable. 3 studies deal with the benefits of having solid walls rather than fabric curtains to separate patients being examined or having a personal interview. As a variation on this theme, one study deals with the advantages of having fixed walls rather than an open plan solution with curtains in a ward for terminal patients. One study deals with the effect of color and other decorative changes on agitated and aggressive children made in one of five rooms meant for quiet relaxation. However, none of these cases deals directly with healing effects let alone physiology effects but rather with patient satisfaction and behavioral effects.

9.1.05 Conclusion regarding "Healing Architecture"

In conclusion, none of the studies referred fulfilled all criteria. However, it can be concluded that 1) perception can influence healing, at least when it concerns natural scenes, 2) two mechanisms have been suggested, namely distraction and stress and 3) a

theory which can lead to generalizations must contain a statement about the physiological mechanisms it is supposed to work through.

9.2 Evidence Based Design (EBD)

The majority of studies in “Helende Arkitektur” (Frandsen et al. 2009) is made according to the concept ‘evidence based design’ (EBD) which to some extent explains why perceptible architectural futures do not figure among the variables investigated as, according to one of its founders, Krik Hamilton, “design quality is not among the categories” that EBD deals with (Hamilton, 2004b). EBD refers to the corresponding introduction of the concept of 'evidence-based medicine' (EBM) within the medical profession (Martin, 2000; Hamilton, 2002; Hamilton, 2004a). However, EBM is not in itself a research method but a procedure for systematic search, transfer and implementation of results from the very large body of existing medical research into clinical practice, which has been made relevant by the fact that only 15-40 % or even less of medical decisions are estimated to be taken on the basis of scientific evidence (Antes et al. 1999). However, a comparable body of quantified research in architecture from which to draw results does not exist, and EBD has therefore come to stand as a research method in itself. Hamilton has suggested (Hamilton, 2004b) that the knowledge base should be built up in parallel with actual hospital projects by practicing architects and has for that purpose suggested that a four level division amongst evidence-based hospital projects, in which level-four-practitioners have to measure results and report them “to the rigor of peer review and meet academic standards of validity”. For the purpose a certification systems (EDAC) is set up to ensure that the practitioners can meet the academic demands, and a process is described. This process involves that ,as a part of the design process, the architect must “Hypothesize the intended result(s)”of the design interventions under investigation, and subsequently “Carefully measure the results” and “Report unbiased findings from an independent source” (Hamilton, 2004b). Apart from the questions that can be raised on the possibility of unbiased reports under these circumstances, there are a couple of other methodological issues of relevance in this context. First, it must be noted that this is precisely the type of “very specific questions relating to specific observations” (Thompson 2006, p. 14) that, according to Thompson, led to an incapacity to construct broader theories. Secondly, the hypotheses of EBD do not refer to an explanatory theory

like those of EBM, those Stankos and Schwarz states (2007) that: "…EBD is embedded in a knowledge base that can hardly provide an explanatory theory, and therefore cannot be used to understand why some design solutions work and others do not" as the role of the theories that EBD lacks is exactly to "describe what is happening and to predict what will happen" (Stankos and Schwarz, 2007). In the case of EBD, the role of the hypothesis is limited to the registration of a possible causal relationship in a very specific instance. This potential lack of ability to predict might seriously question the value of EBD as an relevant design tool. Thirdly, it must of course be mentioned that it might in many instances be very difficult to determine which parts of a design intervention are responsible for a measurable effect, as soon as the complexity rises above the level of e.g. installing a new sound absorbing ceiling.

9.2.01 Conclusion regarding EBD

To conclude: basically nothing prevents EBD to fulfill the three criteria: A (architecture), B (perception) and C (physiological effect). In fact, some of the research on landscape links perception and physiological effect, but does not deal with architecture. However, the methodology of EBD, where the hypothesis is not tied to a theoretical framework and only accounts for the expected outcome, makes it difficult to generalize to other contexts which differ from those in which the study was made. EBD deals with many aspects of healthcare design, but in those cases in which it deals with physiological effects of the patients' interaction with the environment, the body and the physiological processes that occur in it is considered a "black box", as depicted in Fig. 9.1.

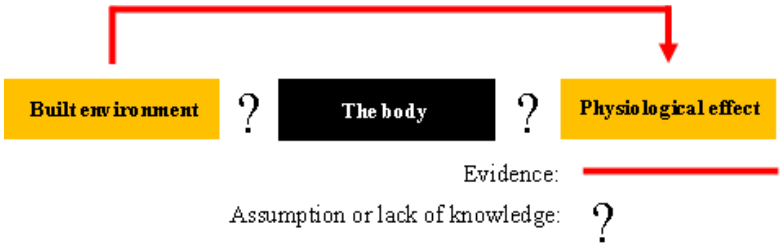

Fig. 9.1. In the the methodology of EBD, the hypothesis is in general not tied to a theoretical framework, as the body in which the physiological processes it triees to predict is considered a "black box".

9.3 Theories based on medical knowledge

In Denmark Lars Hesleth, former physician and director of research at “Rigshospitalet”, the largest hospital in Denmark , and Kim Dirckinck-Holmfeldt, architect and author, have written about how they imagine that the architectural design and use of art can enhance the healing at future hospitals. In 2007 they edited the book “Sansernes Hospital” (“The Hospital of the Senses”) which, beyond their own contributions on physiology and architecture, contains contributions from prominent Danish artists. Part of the book’s mission is to advocate for the establishment of a new “Rigshospitalet”, and its comprehensive descriptions of the history of hospital design in Denmark as well as the shortcomings of the of mid- and late 20th century design principles must be seen in this light. The main argument is divided into two phases: 1) a scientifically well founded, but popular presentation of the relationship between stress and the immune system, pointing to some of the same sources of stress as EBD, e.g. noise and 2) a discussion of architectural space. Unfortunately, the authors refrain from trying to make a clear connection between spatial architectural qualities and stress, and thereby immune function. On the contrary, spatial qualities are considered in essence too subjective, and it is “not possible to conduct studies based on evidence of the experience of subjective

space, unless one is satisfied with the analyses of primitive and stereotyped spatial types"[5] (Hesleth and Dirckinck-Holmfeldt, 2007, p. 256).

In the US, medical researcher and director of research at the Arizona center of Integrative Medicine, Esther M. Sternberg has written about brain – immune – environment relationships. She has first and foremost pointed to two mechanisms, namely the stress systems (Sterberg, 2001, pp. 55-91 and pp. 109-132;) and the placebo effect (Sternberg, 2001, pp. 159-180; Sternberg 2009, pp. 193-214), by which the environment could influence the immune system. She also suggests two mechanisms by which mainly the stress system might by influenced by the perception of the environment. First she, with design strategies used by the Walt Disney group for the design of Disney world amusement parks as model, suggests that way-finding systems and sequential passage through places might be used to modulate the stress system. This is in contrast to the, with scientific evidence very thoroughly substantiated, presentation of the relationship between brain systems and the immune system. Secondly, referring to evidence from numerous animal experiments, she suggests that places can be made to produce physiological effects through the so called conditioned place effect (Sternberg, 2001,121-128 ; Sternberg 2009, pp. 158-161 and p. 290).

9.4 Conclusion

In conclusion, both Hesleth & Dirckinck-Holmfeldt and Esther M. Sternberg, due to the comprehensive medical knowledge they have access to, have presented convincing arguments for mechanisms through which physiological effects can influence healing and well-being. However, they have not presented convincing suggestions to a connection between these physiological mechanisms and the proposed influence on them by the perception of the built environment. Just as the body is handled as a black-box in the case of EBD, they can be said to handle the built environment in a black-box like fashion. Though explanations and analysis of the built environment are attempted, it remains on a

[5]"….er det ikke muligt at gennemfører evidensstudier af subjektive rumopfattelser, medmindre man slår sig til tåls med analyser af primitive og skabelonagtige rumtyper".

speculative level and the connection is never convincingly established. In order to establish where there is a need for research efforts to bring this field ahead, the situation is summarized in Fig. 9.2.

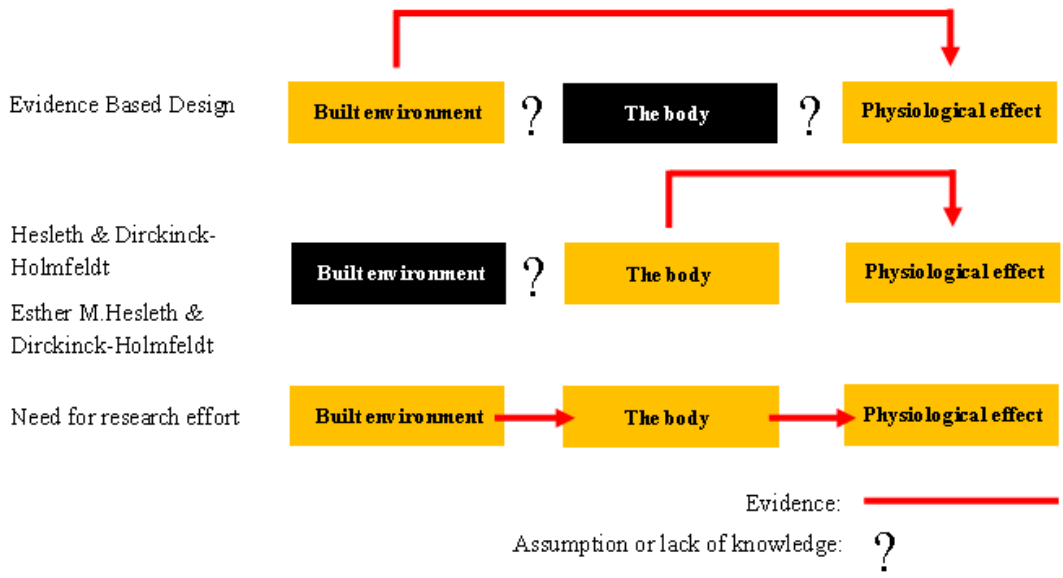

Fig. 9.2. Just as the body is handled as a black-box in the case of EBD, Hesleth & Dirckinck-Holmfeldt and Esther M. Sternberg can be said to handle the built environment in a black-box like fashion. This defines the research effort needed rather precise. It must be attempted to establish a theoretical understanding, were the build environment is the variable, the link between the build environment at the body must have the charater of perception and not just refleczive reactions to e.g. amounts of light or sound, and the prediction of its effect must be based on an understanding of the physiological processes that generates them.

In the light of the effort put into establishing such an understanding up until now, it would be pretentious to have any ambition of coming up with a contribution that would be more

than just a small step closer to an understanding. However, the state of the art points to some conclusions concerning the content of the research projects that will make up the next step towards an understanding regarding whether the perception of the built environment can influence healing or not:

- The architecture must be the variable
- The effect must be generated by a process involving the perception of architecture, and not just the amount of environmental factors.
- Falsifying hypothesis must be drawn from an underlying physiologically based theory, which constitutes an attempt to explain and understand the underlying mechanisms.

Furthermore, it is worth noting that three mechanisms or effects through which architecture could be imagined to work on health have been mentioned: stress, distraction and the placebo effect.

10

An assumption regarding the relationship between mind and body.

The topic of this thesis inevitably involves the question of how perception interacts with the body. As perception traditionally is associated with the mind/consciousness, this just as inevitably involves taking a stance concerning the classical mind-body problem, which is still subject to intense debate, not least made relevant by the perceived advances in neuroscience and "artificial intelligence". In this chapter some of the most important positions will briefly be discussed and, since the problem is unresolved, an informed stance will be taken as a basis for thesis.

As noted, it has since the Enlightenment been possible by and large to regard research in architecture as research in humans, and at hand is all the traditions of research and all the sciences that deals with humans; the challenge is to pick the relevant ones in the context of the inquiry at hand. In an inquiry concerned with the question whether architecture can influence healing, it is obvious that physiology must be one of them. Since architecture works through the senses, the question is then how perception can influence physiology. This makes it necessary to take a stance concerning the classic mind-body problem, as perception traditionally is connected with consciousness – the mind – and health with the operations of the body (Blackburn 1996 pp. 280-281). The question is, if the physical, biological operations of the body correctly can be regarded as comparable with the mental phenomenon of perception, and thereby be studied with the same methods.

The agenda for the debate was set by Descartes (1596 – 1650) with his philosophy of dualism, dividing existence into the mind/soul - *res cognitas* - and matter – *res extensa*. The soul was regarded as immaterial while the bodies of humans as well as animals were

regarded as machines – *res automata* - belonging exclusively to res extensa and governed exclusively by the laws of physics. Descartes believed that body and soul communicated through the pineal gland, but this idea had to be given up and this led to the idea of parallelism in which the mind and body are perceived as two independent worlds.

The problem of the theory is that it is difficult to explain the interaction of mind and body eg. how is it possible for the mind willfully to move the body which has no will of its own, and how is it possible for the soul to sense bodily sensations eg. pain.

In parallelism the mind and body are then envisioned as two synchronized clocks set in motion by god so that a decision to move the body would appear synchronously with the actual move of the body, but without any causal link between them. However, this forces the mind to be just as deterministic as the body (Russel, 2004 pp. 514-515; Cooper, 1996 pp. 252-255).

Though dualism still has its defenders (Warner 1995, pp. 343-354), subsequent models have therefore all in different ways tried to collapse Descartes' two categories into one. Broadly speaking idealism on the one side holds that reality is all mental in nature (Blackburn 1996 p.184) and monism, materialism, naturalism, physicalism and others on the other hand hold that reality is material in nature (Blackburn, 1996, p. 248, 255, 287). A special version of monism called neutral monism, in which matter is in itself neither mental nor physical but capable of both attributes was put forward by William James (Blackburn, 1996, p. 260; James, 1912/2003, pp. 110-122). The debate about the mind-body problem has been going on at least since Decartes, by in this context the discussion will be restricted to the recent development, which has shaped the positions as the more or less is today. Two major movements that has been very influential to the debate in the midst 20th century is behaviorism and cognitive science. Behaviorism is the belief, that mental states are just dispositions for behavior and that therefore a straightforward causal link between stimuli and behavior exists (Blackburn 1996 pp. 39-40). Cognitive science more or less succeeded behaviorism and broadly speaking took over its belief in causal links between stimuli and behavior, though in a more complex way. Many cognitive scientists relies on the philosophy of functionalism, which claims, that “intelligent functions carried out by different machines reflect the same underlying process” (LeDoux, 1999, p.27), which has led to the comparison of the mind with a computer

program running on the hardware of the brain (Blackburn, 1996, pp. 150-151). Cognitive science and functionalism therefore came to provide the foundation of the "strong artificial intelligence" movement, which claims that provided with the right software a computer can have a mind fully comparable with a human mind (Searl, 1995; p. 292; Blackburn 1996 p. 26). Though cognitive science represented a step forward compared to behaviorism as "the cognitive movement brought the mind back to psychology" (Le Doux, 1999, p. 27), the idea of functionalism at the same time restricted it to deal with unconscious and un-emotional processes (LeDoux, 1999, p.35). The advances of neuroscience has however made the question about consciousness, emotions, feelings and how unconscious processes interact with consciousness actual, and has raised difficult questions about how these basically subjective phenomenon can be studied scientifically (LeDoux, 1999, pp. 40-41; Panksepp, 2005,pp. 302-306).

Two factors seems to have made the process of unifying the Cartesian categories of res cognitas, res extensa/ res automata difficult and awkward:

First, the intuitive terror that some have felt of having the soul turned into matter, or even worse, into res automata, has stood in the way. Thus Peirce writes: "The old dualistic notion of mind and matter, so prominent in Cartesianism, as two radically different kinds of substance, will hardly find defenders to-day……The materialistic doctrine seems to me quite as repugnant to scientific logic as to common sense; since it requires us to suppose that a certain kind of mechanism will feel, which would be a hypothesis absolutely irreducible to reason" (Peirce, 1891, vol. 1 p. 292) after which he rejects monism of James as well and goes into a sophisticated and complex defense of idealism. So strong has the Cartesian picture of matter and "res automata" been that when considering if the mind could be made up of matter as well, the only possibility under consideration seems to have been that the concept of mind or consciousness as a consequence somehow had to be reduced to a state of simplicity or non-existence that matched the image of "res automata". An example could be Francis Crick, writing in the introduction to his book "The Astonishing Hypothesis; The scientific search for the soul": "The Astonishing Hypothesis is that "You", your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact *no more than* the behavior of a vast assembly of nerve cells and their associated molecules" (Crick,

1995 p.3; added italics). It is difficult to understand why the phenomenon under study, the consciousness, should suddenly be any simpler than it used to be, as indicated by Crick's phrase "*no more than"*, just by being regarded as matter rather than immaterial. There seems to be an inherited reluctance to consider altering the other side of the equation, which is to recognize, that matter can do infinitely more complex things than what is associated with the barren image of "res automata".

The second reason is related to the theory of science. According to John Searl (1995) the common problem of all the concepts mentioned is that the collapse of dualism's two categories into one has never been completed. In dualism "res cognitas" represented everything which is subjective and qualitative in terms of mental feeling states such as happiness, sorrow or pain while matter – "res extensa" – represented everything which is objective. Since the hallmark of science is to strive to be objective, presupposing that the reality it describes is objective, it has been hard to accept that matter through the fusion of the categories under certain circumstances could be endowed with subjective properties. This has led to the peculiar situation that several philosophical stances more or less deny the existence of subjective mental states or even consciousness altogether. According to Searl, the problem arises from failing to realize that "There is a distinction between answers to the question, What is it? (ontology), How do we find out about it? (epistemology), and What does it do? (causation)." (Searl, 1995, p. 289). The mix-up of ontology, epistemology and causation according to Searl arise out of a reluctance to accept an ontology of or about the subjective. If an objective ontology of the mind is maintained, it must lead to the denial of the existence of subjective mental states and an emphasis on what is objectively describable, namely behavior, and the result will be behaviorism. If this becomes unacceptable an emphasis can be on causation, and attempts can be made to describe mental states as causal relations or computations, which is functionalism and "strong artificial intelligence" (Searl, 1995, pp.289-296). In this way, what has happened in the name of science is rather a denial of "res cognitas" than a fusion, and hence these positions still stand for an acceptance of the Cartesian categories, and in some ways of the dualistic concept of the world (Searl, 1995, pp. 295-296). The solution to the problem according to Searl is simply to maintain an objective epistemology and causality, while accepting that an objective ontology can deal with the subjectivity of the mind. If one is indeed a true materialist, subjective mental states must

be regarded as biological states of the brain, and as long as objective scientific methods (epistemology) are used, there should be nothing problematic in the scientific study of them (Searl 1995, pp. 292-293). This leads him to offer the following answer to the mind-body problem: “mental phenomena are caused by neurophysiological processes in the brain and are themselves features of the brain” which he names “biological naturalism” (Searl, 1995, p. 277). This however seems odd, as he unambiguously and unmistakably states this as an answer to the mind-body problem, and the body is nowhere to be found in the sentence. By this Searl himself apparently commits a sort of cartesianism, at odds with a certain branch of neuroscience which, by studying the brain in isolation, seems to have shifted the problem from a mind-body problem to a brain-body problem. In contrast to this stands the neuroscientists Antonio Damasio, who states that: “There may be some Cartesian disembodiment also behind the thinking of neuroscientists who insist that the mind can be fully explained solely in terms of brain events, leaving by the wayside the rest of the organism and the surrounding physical and social environment” (Damasio, 1994, pp. 250-251). This brings the discussion right to the heart of this thesis: “The idea of a disembodied mind also seems to have shaped the peculiar way in which Western medicine approaches the study and treatment of diseases…… The Cartesian split pervades both research and practice. As a result, the psychological consequences of diseases of the body proper, the so-called real diseases, are usually disregarded and only considered on second thought. Even more neglected are the reverse, the body-proper effects of psychological conflict.” (Damasio, 1994, p. 251)

Seen in this light, it must be sound, despite the fact that the mind-body question is not resolved and probably will not be in a foreseeable future if ever, to take a reformulated version of Searl's “biological naturalism” as a point of departure, since this seems to represent an option that is at least not unlikely. The reformulated “biological realism” could be something like this: “Mental phenomena are caused by neurophysiological and other biological processes within an organism in interaction with its environment, and are themselves features of the organism according to its inherent mental capacity”. By this it is underlined, that mental phenomenon’s is something that happens in the organism as such, and no distinction is made regarding the mind/brain and body. Furthermore, it is underlined, that is underlined, that the organism is not seen in isolation, but as interacting with its environment.

Indicative of the admissibility of this concept could be that it has no problem with fitting into an evolutionary perspective. Neither does it have a problem explaining how chemical substances can alter perception and consciousness (eg. alchohol or narcotics) or cause it to disappear temporarily (anesthesia), or how physical damage to the brain, of which the catalog is long and tragic, or body (eg. phantom limb pain) can change it.

The acceptance of this principle is extremely important for the course of the inquiry, because this implies that perception can be seen basically as a physiological function in line with other physiological functions, and the inquiry can then be concentrated on understanding the interplay between physiological processes constituting perception and governing health.

11

A definition of Health

To answer the question ”Can architecture affect health?” a definition of what is meant by health and disease is needed. In this chapter problems of defining health as well as disease will briefly be discussed, and a definition will be established as a basis for thesis.

The official definition of health and disease, signed by all member countries of the UN, is that of the WHO (UN, 1946) which states that: “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” and goes on to state that “The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being…..”. However, for several reasons this has proved to be an inadequate definition by professional standards, and must rather be seen as a political statement of intent.

First, it actually does not define what is meant by physical, mental or social well-being or, what is meant by disease. Secondly, it is questionable if it makes biological sense to separate health and disease as it does by stating that well-being is “not merely the absence of disease”.

According to Wylie (1970) the late 19th and early 20th centuries were dominated by a belief that each disease had a specific cause, and thereby could be ascribed to a certain malfunction. Thus diagnosis, treatment and prevention of disease became easily definable cornerstones of the health care system. However, this concept had to be given up, as it became apparent that disease usually has multiple causes, which gave birth to a doctrine based on the interplay between host, agent and environment, which became widely accepted. With this recognition follows an understanding of disease as a dynamic concept, and thereby of well-being and disease as rather being two opposites on the same scale. In addition to this comes the recognition that among the multiple causes of diseases or lack of well-being can be major negative private life events like divorce, bereavement etc. of which the desirable absence hardly can be covered by any declaration of human

rights (Wiley, 1970). This makes Wiley, in the recognition that the environment is an ever changing dynamic entity, propose the following definition: “Health is the perfect, *continuing* adjustment of an organism to its environment”, actually a revised version of an older one by Herbert Spencer (1820-1903) (Wiley, 1970). Conversely what is called disease must be seen as a maladaptation to the environment. Though this definition has been criticized by some for being too abstract to be operational (Jette, 1979) it has proven operational to others. Thus Das (2011) notes that Wiley’s definition implies that: “biochemical changes that are outside the normal range will be considered imperfect adjustments and indicate that the person is having a disease. Thus, this definition implies that if the abnormal biochemical changes are restored to normal, then the person is pronounced as normal”. As an indication for a biochemical imbalance which Das points out, an extensive range of diseases signaling molecules of the immune system (cytokins) can simply be used as indicators (Das, 2011, pp. 11-12).

Though there is no generally accepted definition of disease, health or well-being, Wiley’s definition will be used as the basis for the discussion of those topics in this dissertation, as it appears to enjoy broad support, even though it is not accepted by all.

Three very important implications follow.

First, the definition indicates that health is caused by the organism’s ability to adapt as well as the environment's ability to meet the demands of the organism. In other words, a state of threatened well-being, compromised health or disease might just as well be due to the organisms’ inability to adapt, as it might be due to an environment that transgresses the organism's inherited capacity for adaption.

Secondly, the emphasis on adaption to the environment touches upon the concept of homeostasis, which is today central for the understanding of physiological processes. The concept was put forward by the American physiologist Walter B. Cannon (1871-1945). In his original paper Cannon specifically cites some of his inspirational sources, among those the French physiologist Charles Robert Richet (1850 – 1935): “The living being is stable. It must be in order not to be destroyed, dissolved or disintegrated by the colossal forces, often adverse, which surround it. By an apparent contradiction it maintains its stability only if it is excitable and capable of modifying itself according to external

stimuli and adjusting its response to the stimulation. In a sense, it is stable because it is modifiable – the slight instability is the necessary condition for the true stability of the organism" (Richet, 1900 cited in Cannon 1929). Another very important source for Cannon was another Frenchman, the physiologist Claude Bernard (1813-1878) who wrote: "It is the fixity of the 'milieu intérieur' which is the condition of free and independent life….. all the vital mechanisms, however varied they may be, have only one object, that of preserving constant conditions of life in the internal environment" (Bernard, 1878, p. 113 and p. 121 cited in Cannon 1929). This leads Cannon to define "homeostasis", or in its adjective form "the homeostatic balance", as: "the coordinated physiological reactions which maintain most of the steady states of the body….and which are so peculiar to the living organism" (Cannon, 1929). In other words, the trick of staying alive for any organism is to keep the internal biochemical balance within narrow biochemical boundaries despite the variability of the outer environment, through a process of on-going adaptation. Organisms that cannot do this (or cannot reproduce) simply are not here. It now becomes apparent that it is exactly the keeping of the homeostatic balance through adaptation that Wiley is aiming at with his definition of health: "Health is the perfect, *continuing* adjustment of an organism to its environment" (Wiley, 1970). Conversely, compromised health or well-being can be understood as compromised homeostasis.

Thirdly, it has become apparent that health, well-being and disease cannot be discussed separately, but should rather be seen as a scale with a smooth transition from perfect biological adaptation and well-being in the one extreme to total biochemical maladaptation and imbalance in the other extreme. It is not an on-off situation with a clear and well defined distinction between balance and imbalance, between being well and being ill. Consequently, it is not possible to make an inquiry into "healing architecture" as an isolated topic; it is not possible to make a clear distinction between architecture that is healing and architecture that is not or is indifferent to health. Rather the study must try to uncover whether perception of the environment can influence the homeostatic balance and if so, how the properties of the built environment systematically can do so. Consequently, the discussion from now on should not be restricted to healing, but must be on health, healing and well-being.

In the end of the last chapter, it was established that a reasonable way to approach the problem at hand is to understand the problem as interplay between the distinct physiological processes which constitute perception and govern health, healing and well-being. This list can now be made more precise as, following Wiley and Cannon, the processes that govern health, healing and well-being are those governing homeostasis: the interplay between the endocrine, immune and nervous system (Damasio, 2000, p. 40).

12

Architecture and the biology of consciousness

In the last chapter, it was concluded that an inquiry into whether the perception of architecture can influence health, healing and well-being, necessarily must investigate whether the perception of architecture can influence the homeostatic balance. The purpose of this chapter thus is to arrive at a theoretical understanding of architecture, based on an identification of the various ways in which architecture might interact with the organism directly or indirectly related to homeostasis.

The most publicized attempt to understand perception of aesthetic valance in terms of biology has probably been the movement of neuroasthetics, which was advanced by the neuroscientist Semir Zeki. Zeki deliberately limits his inquiry by restricting himself from the emotional content of art and "its ability to disturb and arouse and surprise"(Zeki, 1999, p.5) and rather concentrates on finding the "Neural Correlates of Beauty" (Kaeabata and Zeki, 2004, pp. 1699-1705) which he envisions are represented in the brain independently of emotions. First, there is not much in the search for the neural correlate of beauty that holds a promise of leading to a more comprehensive understanding of how the perception of architecture might influence homeostasis. Secondly, the relevance of an isolated search for the neural correlate of "beauty" has rightfully been questioned. Thus Conway and Rehding, commenting on the neuroaesthetics of Zeki, write: "Large swaths of twentieth-century art have greatly expanded – or entirely disavowed – notions of beauty. Such distinctions may seem picky, but interdisciplinary work such as neuroaesthetics relies on shared principles, and requires heightened attention to conceptual clarity" (Conway and Rehding, 2013). A study of architecture based on a biological understanding must therefore, besides biology, take the understanding of the objectives of architecture within the discipline itself into account. Reading statements by one of the leading theorist within the discipline of architecture such as Juhani Pallasmaa like: "Profound architecture does not merely beautify the settings of dwellings; great

buildings articulate the experience of our very existence" (Pallasmaa, 2012, p.19) and "Architecture, as with all art, is fundamentally confronted with questions of human existence in space and time, it expresses and relates man's being in the world. Architecture is deeply engaged in the metaphysical questions of the self and the world, interiority and exteriority, time and duration, life and death" (Pallasmaa, 2008, p. 16), implies that something much deeper than the search for beauty is at stake. Besides this, the very idea of investigating art by looking for brain reactions to beauty has been seriously challenged on empirical grounds within neuroscience itself. Brown and colleagues (Brown et al., 2011) concluded from a meta-analysis of 93 neuroimaging studies of positive aesthetic valance that art is treated as any other object by the brain, when it comes to aesthetic valance. They conclude that "Aesthetic processing, at its core, can thus be equated with object-appraisal processes, resulting in emotions that sit along the spectrum from transcendence to repulsion". Most interestingly they found that the single common denominator among brain centres implicated in valence processing for all the studies reviewed, was a centre called the insula. The insula represents an interesting combination of possessing the highest degree of body-representation in the brain and being involved in the generation of subjective feeling states as well as the generation of the "material me" or "sentiment self" (Craig, 2009). This seems to confirm that the experience of subjective aesthetic valance is closely related to the body and generation of the self and consciousness, as implied by Pallasmaa. Thus an understanding based on biology must rather be found among theories which include the whole organism in constructing an understanding of perception and consciousness. The most comprehensive neurobiological theory of the integration of bodily presence, the self, consciousness and the environment is found in the comprehensive authorship of the American neuroscientists Antonio Damasio.

12.1 Biological value

In chapter 11 it was concluded that the homeostatic balance is the key to the understanding of health and well-being in general as well as healing, in particular. This among neuroscientists further qualifies Damasio specifically, as he takes homeostasis as the point of departure of his model. To ensure that the homeostatic balance can be kept Damasio notes, it is necessary for *any* organism to be able to find sources of energy,

incorporate and transform energy, maintain the chemical balance of the interior compatible with the life processes, maintain the organism's structure by repairing its wear and tear and to fend off external agents of disease and physical injury (Damasio, 2004a, p. 30). An organism that cannot do this (or cannot reproduce) simply cannot exist.

By this, Damasio notes, biological value and intentionality have been introduced (Damasio, 2010, pp. 25-28). Although primitive single-celled organisms do not possess the means to perceive it, there are “good” things and actions that sustain homoeostasis and thereby survival, and there are “bad” things that threaten homoeostasis, which can lead to extinction. As organisms have become more complex, homeostatic regulation has become equally more advanced. Values have been implemented as drives and instincts and administrated by reward and punishment devices (Damasio, 2010, p. 55 and p. 109).

12.2 Emotions

The key to the understanding of homeostasis and how the organism relates to its environment both in terms of physiology and psychology has shown to be the study of emotions and the causative sequence that leads to emotions and conscious feeling. In the historical retrospect, this has proven to be one of the most important discussions in psychology and neuroscience within the past one and a half century. In the following the major concepts and the different relationships between them, as proposed by different models, will be discussed through a brief historical overview of some of the main positions.

The starting point was the so called James-Lange theory, named after William James and the Danish physician and psychologist Carl Georg Lange (1834 – 1900) who independently put it forward. The core of the James-Lange theory as expressed in William James paper from 1884 “What is an Emotion?” is to reverse the intuitive concept of the order of events, when emotions and feelings occur. The famous standard example from William James' text is that if one walks in the wood and sees a bear, the course of events that we intuitively imagine is that first we become afraid of the bear, which is a mental reaction, and then run away, which is a bodily reaction. William James claims that the opposite is the case: that we see the bear, run away, and become afraid because we run away. In other words, the bodily reaction follows directly the perception and causes the

mental reaction. Thus “we feel sorry because we cry, angry because we strike, afraid because we tremble, and not that we cry, strike, or tremble, because we are sorry, angry, or fearful, as the case may be.” (James, 1884). The thesis that James puts forward is then that “Our natural way of thinking about these standard emotions is that the mental perception of some facts excites the mental affection called the emotion, and that this latter state of mind gives rise to the bodily expression. My thesis on the contrary is that *the bodily changes follow directly the* PERCEPTION *of the exciting fact, and that our feeling of the same changes as they occur* IS *the emotion*”. (James, 1884). The revolutionary idea of James and Lange was of course that they reversed the intuitive sequence of events by stating that the bodily changes follow directly the perception, and that the feeling is caused by the bodily changes and not the reverse. However, as Damasio has pointed out, James confuses matters by first separating emotions and feelings conceptually, and then in the end stating that the “feeling IS the emotion”. (Damasio, 2010, p. 115). Walter B. Cannon challenged the James-Lange theory in two papers, from 1927 and 1931. Cannon refers to animal experiments in which the spinal cord as well as the vagus nerve (which forms a parallel connection to the spinal cord between body and brain) have been cut in dogs, and to cats who had the entire sympathetic division of the autonomic nervous system removed. In both cases it had little if any effect on the animal’s capability to show emotions e.g. anger, joy, disgust or fear, and Canon thus concluded that the sequence of events described by the James-Lange theory was wrong, as the animals were capable of expressing emotions despite these destructive interferences in their nervous systems (Cannon, 1927). The conclusion that the James-Lange theory could be abolished however rests on the contradictory nomenclature which confuses emotions and feelings, as pointed out by Damasio (Damasio 2010, p. 115). The core of the James-Lange theory is that the bodily reaction produces the conscious feeling through a sensing of the body as it reacts e.g. “we feel sorry because we cry” (James, 1884). It is therefore not at odds with the James-Lange theory that these animals can produce bodily expressions of emotions. Rather the question is whether these emotional expressions can produce conscious feelings when the connections *from* the body *to* the brain are cut, and the animal's ability to sense its own bodily reaction thereby is compromised. Whether conscious feeling arises under these or any other circumstances can of course not be established through animal experiments. Although the connection from the body to the brain in practice cannot be entirely abolished, because chemical

signals travelling through the bloodstream and signals from the cranial nerves always will remain, studies of humans with severe injuries in the nerve connections between body and brain, especially in cases of the so called locked-in-syndrome, have shown that there is indeed a marked change in the ability to produce conscious feeling (Damasio, 2000, pp. 292-293; Damasio, 2010, pp. 234-235). However, after the criticism by Cannon, the James-Lange theory was largely forgotten and by the 1960s and throughout the 1970s there was in psychology almost consensus about a cognitive model in which a sequence was envisioned consisting of perception, a cognitive appraisal process and a resulting emotion**.** One of the leading proponents of the cognitive model was the psychologist Richard Lazarus (1922-2002). His position was that an emotion came about through a single cognitive appraisal process that mediated the relationship between the person and the environment (Lazarus, 1982). However, in 1980 the American psychologist Robert Zajonc (1923-2008) published a paper entitled “Feeling and Thinking; Preferences Need No Inferences” which partly was based on his own and others' empirical studies. He argued that emotional processes might constitute a process different from and faster than cognition: “In fact, it is entirely possible that the very first stage of the organism’s reaction to stimuli and the very first elements in retrieval are affective. It is further possible that we can like something or be afraid of it before we know precisely what it is and perhaps even without knowing what it is” (Zajonc, 1980). This led to a long controversy, which only ended when neuroscience in the 1990s began to offer insights into the neurophysiological basis of appraisal, emotion and feeling. The American neuroscientist Jospeh LeDoux worked with training rats through a process known as fear conditioning by giving them a mild electrical foot shock immediately followed by a sound. After some training, the rats exhibited the same emotional fear reaction when hearing the sound without receiving the foot shock. He then discovered that even if the connection from the rat's ear to its auditory cortex was cut, the rat still reacted with fear to the sound, which made him conclude that some parallel mechanism triggered the fear response (LeDoux 1999, p. 152, LeDoux, 2002). Neuroanatomical studies revealed that the brain structure responsible for the emotional fear reaction was the amygdala, a part of the so called limbic system (LeDoux 1999, 150-165). Thus LeDoux developed the theory that the amygdala receives fast, but not highly processed signals directly from the thalamus enabling a fast reaction, and a slower but more thoroughly analyzed signal from the auditory cortex, enabling the organism to react fast when required and to adjust its

behavior as more detailed information becomes available. Thus appraisals in this model are carried out by the amygdala, and as the amygdala along with other limbic structures operates outside conscious control or awareness (LeDoux 1999, p. 20-21; p. 30-35), the conclusion is that the appraisal process that triggers emotional reactions is indeed fast and non-conscious. The work of LeDoux has been very influential and has, perhaps because his point of departure in the first place was fear conditioning, given the amygdala the nickname “the brain's fear center” in popular conception. However, several studies have demonstrated that the amygdala is also involved in some positive valance appraisal (Garavan et al., 200;Yang et al., 2002) and in spatial tasks, such a regulating personal space (Kennedy et al., 2009). It seems that the amygdala performs rather a double role in determining the biological relevance for the organism ("what is it") and what action it should trigger ("what's to be done"). Furthermore, the amygdala seems to have a central role in the disposition of the organism's limited resources of awareness, and in decision making. Interestingly, it seems that especially the human amygdala is particularly sensitive to the framework in which an event occurs (Pessoa, 2011). It has subsequently been found that perceptual signals besides being processed in the respective cortical areas of which some are involved in producing the conscious sensory experience, are widely spread among sub-cortical, non-conscious structures in the limbic system and brain stem, as illustrated by the visual pathways in fig. 12.1.

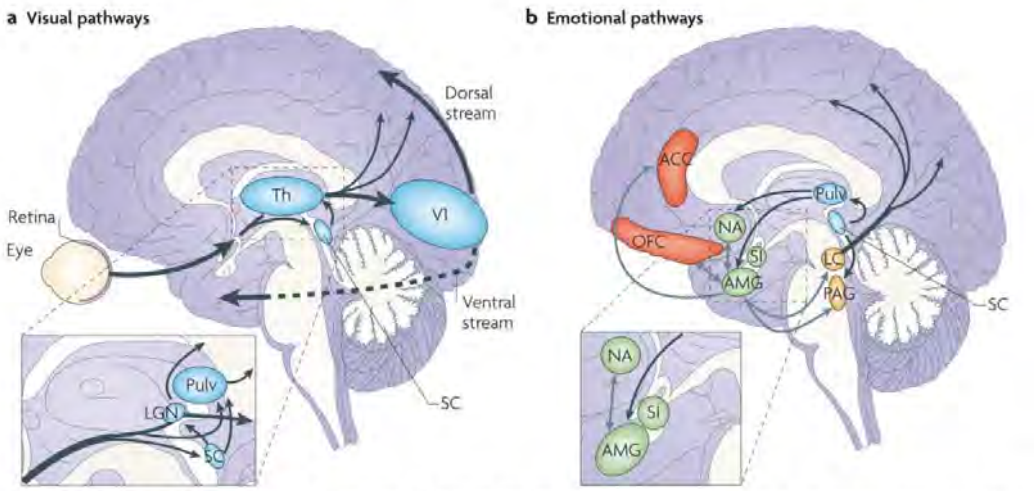

Figure 1 | **Cortical and subcortical pathways for vision and emotion. a** | The primary visual pathway (shown by thick arrows) originates from the retina and projects to the primary visual cortex (V1) in the occipital lobe via an intermediate station in the lateral geniculate nucleus (LGN) of the thalamus (Th). From V1, visual information reaches the extrastriate cortex along the ventral (occipitotemporal) and the dorsal (occipitoparietal) stream. However, a minority of fibres originating from the retina take a secondary route (shown by thin arrows) and reach both the superior colliculus (SC) and the pulvinar (Pulv). These two subcortical sites are connected and also send direct projections to the extrastriate visual cortex, bypassing V1. Another V1-independent visual pathway consists of the direct projections between the superior colliculus and the LGN that, in turn, send efferents to extrastriate cortices in the dorsal stream. **b** | The 'emotion system' includes several cortical and subcortical areas. Among the subcortical structures are the amygdala (AMG) and the substantia innominata (SI; shown in green), which are buried deeply in the temporal lobe and in the basal forebrain, respectively, the nucleus accumbens (NA) in the basal ganglia (shown in green) and brainstem nuclei (shown in yellow), such as the periaqueductal grey (PAG) and the locus coeruleus (LC). Among cortical areas (shown in red) are the orbitofrontal (OFC) and the anterior cingulate cortex (ACC). The visual and emotional systems are extensively interconnected, especially at the subcortical level, where the superior colliculus is connected to the amygdala via the pulvinar. Direct connections also exist between subcortical and cortical emotion regions (for example, between the amygdala and OFC or ACC), between subcortical structures for emotions and cortical visual areas (for example, between the amygdala and temporal cortex) (not shown) and between brainstem nuclei and the cortex via diffuse projections (shown only from the LC). Grey arrows indicate connections within the emotion system.

Fig. 12.1
Besides being processed in the respective cortical areas of which some are involved in producing the conscious sensory experience, perceptual signals are widely spread among non-conscious structures in the limbic system and brain stem, as illustrated by the visual pathways
(From Tamietto and Gelder, 2010)

Thus today the James-Lange theory, with an added non-conscious appraisal process in various modified forms, has become the basis of most modern neurobiological models for understanding of emotions and feelings (Dalgleish, 2004).

By the general acceptance of altered versions of the James-Lange theory, the definition of emotions and feelings that it comprises has been general accepted within neuroscience as well. This is somehow unfortunate, as emotions and feelings in every-day language is used synonymous for feelings. Thus neuroscience dealing with emotions and feelings cannot be communicated before it's peculiar use of these words has been explained, somehow isolating it from common debate. Jaak Pankseep has proposed the term "Affective Neuroscience" – hence the title of this thesis - (Pankseep, , p. 14) covering the study of emotions and feelings. Unfortunately, this term has not court on.

Following the original distinction between emotions and conscious feeling by James, Damasio has defined emotion as: "complex, largely automated programs of *actions* concocted by evolution". Further he notes that homeostatic regulation does not in itself guarantee survival, because in its simplest form it only intervenes when a threatening imbalance already has occurred. Emotional systems should be viewed as systems that are able, through the appraisal of a situation, to address a threatening imbalance in advance through the implementation of preparatory actions (Damasio, 2000. P.44) thus "emotions are part and parcel of the regulation we call homeostasis. It is senseless to discuss them without understanding that aspect of living organisms and vice versa." (Damasio, 2000, pp. 39-40). Therefore the emotional action programs refer to a comprehensive homeostatic regulation that, by combining information about the current state of homeostasis with information from the outside milieu about the situation in which the organism finds itself, strives in advance to bring the body into a position that is most advantageous for obtaining the instantaneous optimal homeostatic balance, by avoiding dangers and achieve fulfillment of biological objectives. The sophistication and efficiency by which they carry out their task makes Damasio term emotions as the "crown jewel of life regulation" (Damasio, 2010, p. 109). The processing in these subcortical structures seems to be essentially different from processing in the later developed cortical areas which among many other qualities contain our advanced capability for object recognition,

etc. Instead the subcortical centers are rather designed for fast processing with the aim to determine when the criteria for triggering a specific action program are present (Damasio et. al., 2000; Damasio 2010 pp.111-114;) and, important to note, if the context to do so is appropriate. Also studies from psychology imply that emotional appraisal takes place on the basis of an entity of the environment and the emotionally charged stimuli (Barret and Kensinger, 2010). In summary, the activation of an emotional program will cover 1) an appraisal process based on a comparison of current state of homeostasis and of whether the external situation meets the criteria for triggering an emotional action program 2) a coordinated and all-encompassing bodily regulation 3) release of a neurotransmitter, chemical compounds that are used to transmit signals between nervous cells, the neurons, in the brain. By altering the communication between neurons in specific networks, the brain's mode of function is altered. 4) Involuntary behavior and social signals e.g. flushing.

12.2.01 The body loop

In contrast, conscious feeling results from a perception of the regulation that takes place in the body and the altered state of mind that comes with the emotional program, or as defined by Damasio, feeling is: "….composite perception of what happens in our body and mind when we are emoting," (Damasio 2010; p.109) . In other words, a feeling is an entirely internal affair consisting of a perception of the altered state of the body including the brain, and the route from emotions to feelings seems to go via the body (LeDoux 1999, p. 302). This is termed *the body loop* (Damasio 1994 p.156; LeDoux 1999 p. 296 – 299; Damasio 2004 p. 62; Damasio 2010 pp. 116 – 119), which in very brief form can be described in this way: limbic structures react, elicit a bodily reaction, which is perceived by other parts of the brain, and experienced as conscious feelings (see fig. 12.2). Thus, there is a marked contrast between the outward directed emotional action programs designed to interact with the environment, and the inward directed feelings, which are basically a sensory perception of the body itself (Damasio, 2000, p. 37). Although the focus here is on the immediate relation to the environment, it should be noted, that the process will roll on. The feeling process might result in the retrieval of relevant memories, which in themselves can trigger new emotional processes and so on (Damasio 1994, pp. 136 – 138, Damasio et al., 2000). However, the theme in this thesis is the

bottom-up reactions that stems from the interaction of the stored and organized in memory, while the interest in the particular context of this thesis is the direct result of perception of the immediate environment, and not the top-down reactions that stems from previous sensations organized into memories.

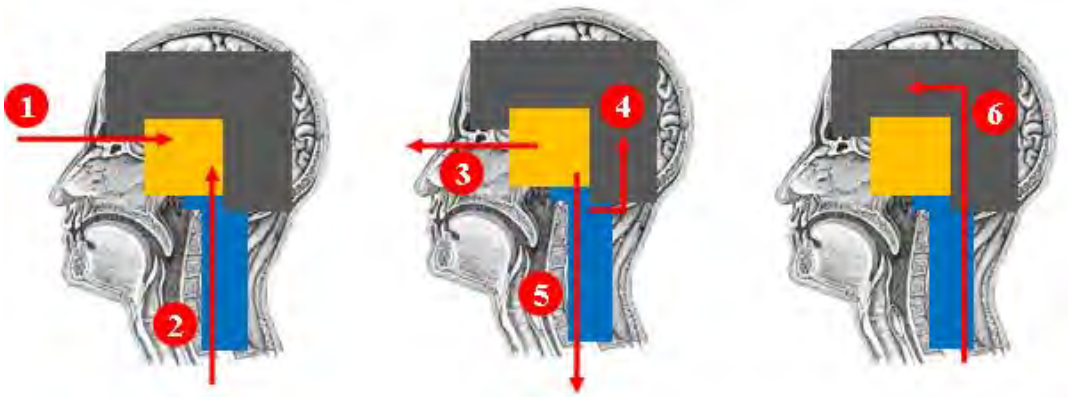

Fig. 12.2. Schematic representation of the emotional sequence. Structures in the limbic system and brain stem 1) receives signals from the sense organs and 2) body holds them together. If something triggers an emotional action program, it will on the basis of 1) and 2) result in involuntary social signals (e.g. flushing) and behavior, 4) adjustments to the brain's neurotransmitter profile and 5) extensive bodily adjustments, with the purpose to enable the organism to cope with the situation and finally 6) signals from the body that reach other structures in the brain that map the body such as the insula, which receives signals from the body via brainstem nuclei, might result in conscious feeling.

As mentioned earlier, Brown et al. (2011) in a metastudy found that the insula, which represents high level body mapping in the brain, was the common denominator for positive valance aesthetic appraisal. They propose a functional connectivity model, in which the appraisal process "comes about through a comparison between subjective awareness of current homeostatic state – as mediated by the anterior insula – and the exteroceptive perception of objects in the environment, as mediated by the sensory pathways leading up to the OFC " (Brown et al. 2011). In other words, aesthetic appraisal of an object in this model comes about, when the feeling content that is generated by a

sensing of the bodily changes elicited by the emotional programs is held together with the highly analyzed sense data, coming from sensory pathways in the neocortex – the meeting of the feeling generated by the object and the analysis of what it is. This model further explains the effect described by Zajonc that we sometimes know if we like a thing before we know what it is (Zajonc 1980), as the feeling content coming via the insula's mapping of the body might at times be faster than the highly analyzed conscious sensory signals.

12.3 Consciousness

The advantage of adding consciousness to the automated and relatively inflexible emotional systems is obvious. In the words of Joseph LeDoux: "While many animals get through life mostly on emotional automatic pilot, those animals that can readily switch from automatic pilot to willful control have a tremendous extra advantage. This advantage depends on the wedding of emotional and cognitive functions." (LeDoux, 1999, p. 175). However, while the different levels of direct life regulation comprise very well researched and understood territories, the understanding of the biology of consciousness is still at a hypothetical stage, subject to controversy. Even so, a lot is known about which structures in the brain are involved in consciousness and which are not, from a variety of sources like the study of brain injuries, pathological conditions like various types of epileptic seizures, the effect of specifically targeted anesthetic compounds and of course the various modern scanning techniques. Furthermore, a lot can be deducted from which neurotransmitters that are exclusively present in the awake brain, as only some circuits depend on these neurotransmitters (Panksepp, 2005, p. 134). From these sources it is also known that consciousness is far from monolithic. It can be partly lost, disturbed or regained, and even awake, normally functional individuals will experience different stages of being more or less intensely conscious. According to Damasio, a working definition of consciousness could be something like this: 1) consciousness is a state of mind in which the organism is awake and a self-process is added to the mind 2) consciousness is a state of mind in which there is knowledge of one's own existence and of the existence of surroundings 3) conscious mind states are always about something and 4) conscious states of mind contain an obligate aspect of feeling (Damasio, 2010, pp. 157-158).

When cells began to form multicellular organisms, two important steps in the evolution of the nervous system are of special relevance in this context. The first was the emergence of neurons which are basically body cells with an ability to influence other cells including other neurons. By this they achieve the capability to transmit signals and build complex networks, and ultimately form centralized, coordinating organs of life regulation in terms of brains. Primitive brains and nervous systems contain only so called dispositional networks, forming organisms that are relatively simple "response machines". When such an organism interacts with an object, signals from its sense organs might through its nervous system activate its motor systems and make it move; there is no record of where the organisms were in the first place or any representations of the object (Damasio, 2010, p. 135). The second important step was the development of an additional type of brain tissue, which is composed of layers of neurons ordered in a precise grid pattern. This allows the brain to create *maps* in the form of patterns of activated neurons, that sometimes rather literally and sometimes rather abstractly represent e.g. sense data. By this the ground was paved for the brain to *represent* the surrounding environment as well as the organism and the brain itself – in fact even the brain mapping itself mapping itself, the environment and the body and so on, in a hierarchical succession. Maps about actual or recalled objects or actions in or outside the body are termed images, which are not to be understood as visual images, but rather patterns created by any internal or external sensory modality. In other words, images occur as a result of the *momentary* mapping of an *interaction* between the organism and an outside object, between the brain and the body or between parts of the brain with other parts of the brain (Damasio, 2010, p. 64, pp. 70-71, p. 158 and p. 187).

12.3.01 Mind and self

In the terminology of neuroscience the mind is defined as the continuous, coordinated flow of such images. The patterns represent things and events located either outside the brain, in the body or in the external world, or inside the brain itself, representing the brain's own processing of other patterns. Mind by this definition is a non-conscious process which is present even in fish and insects (Damasio, 2010, p. 18 and p. 26).

Consciousness appears when a self-process is added to the mind-flow as a knower in the form of an increasing degree of self-representation (Damasio, 2010, pp. 8-9). Just like the

conscious states are not monolithic, the self-processes that produce them when added to the mind are not either. The first step in the self-hierarchy is the proto-self, which occurs when the most stable aspects of the organism are mapped by specific brain stem nuclei in cooperation with cortical areas, perhaps most importantly the insula. The on-going mapping executed by the core-self mechanisms will, moment by moment, report the state of the organism on a range from the optimal to the problematic, producing primordial feelings which occur as a continuous experience of the life process, the homoeostasis, of one's living body “wordless, unadorned, and connected to nothing but sheer existence” (Damasio, 2010, p. 21). Changes in the body state that occur e.g. as a result of an emotional program being launched are registered against the current state of the proto-self (Damasio, 2010, p. 2 and pp. 190-203). Thus, the self that orchestrates consciousness is “the first representative of individual life regulating mechanisms, the guardian and curator of biological value” (Damasio, 2010, p. 183). The primordial feelings run at a scale ranging from pleasure to pain, while “all feelings of emotion are complex musical variations on primordial feelings” (Damasio, 2010, pp. 20-21). It thus seems most likely that when the emotional "action program" is triggered, it corresponds to a particular combination of activity in certain sub-cortical structures like the amygdala. It seems likely that the emotional regulation takes place along certain dimensions, and that specific combinations of these dimension are categorized by consciousness into the experience of specific feelings along behavioral dimensions of the ‘action program’ elicited such as basic psychological well-known behavioral patterns as fight-or-flight, pleasure or displeasure, arousal level or approach or withdrawal. Thus the different categories of feelings like anger, sadness, fear, happiness or disgust correspond with sensing of the bodily regulations along these dimensions of overall bodily and behavioral regulation (Barrett et. al., 2006).

On the next level, the core self introduces the self as a protagonist, by adding a representation of the organism as it interacts with its environment, or in the words of Damasio: “What is being added to the plain mind process and is thus producing a conscious mind is a series of images, namely, an *image* of the organism (provided by the modified proto-self proxy); the *image* of an object-related emotional response (that is, a feeling); and the *image* of the momentarily enhanced causative object.” (Damasio, 2010, p. 203). Interestingly this has great similarities with the functional connectivity model of

Brown et al. The major difference seems to be that the model of Brown et al. only contains the image of the object-related emotional response provided by the insula, and the image of the object provided by orbitofrontal cortex, but does not specifically contain the image of the organism (Brown et al. 2011). Because of the direct relationship of the proto- and core self to the body, they can be said, as an entity, to constitute the “material me” of the organism's here-and-now, while the autobiographical self rather constitutes the “social me” and the “spiritual me” (Damasio, 2010, p. 27).

12.3.02 The autobiographical self

The autobiographical self is about both personhood and identity. As implied by the term, it adds to the core self one's autobiography, both the lived past and the anticipated future. As such, autobiographical consciousness reaches the highest level of knowledge of one’s own existence (Damasio, 2010, pp. 157-158 and p. 168). To understand the autobiographical self it is necessary to have a brief idea about how memory works. Memories are not stored as the end product of sensing, but rather as maps of the original sensory patterns in the early stages of perception as they originally occurred in the early sensory cortices. Remembering happens by the reactivation of these maps in the same early sensory cortices, meaning that memory doesn’t happen by recalling but by *reconstruction*. In this mechanism the old device of dispositional networks is combined with the new one of mapping, so that a much simpler dispositional network placed in so called convergence-divergence zones can activate the maps in the early sensory cortices, after which the sense data are run through the sensory machinery of e.g. the brain's visual system once again, resulting in the reconstruction of the original sense experience and resulting in a renewed adjustment to the core self-mechanism. Relatively few neurons in the activating dispositional networks of the convergence-divergence zone can then bind together maps in distinct, early sensory cortices. In this way, a memory-reconstruction can be built, complete with emotional content and the resulting feeling states, sensimotor patterns of movement and touch, visual, auditory and olfactory experience. Especially the emotional component is important, as the emotional content constitutes a “value stamp” in the form of a “somatic marker” added to original perception, signifying the biological value (Damasio, 1994, pp. 165-204; Damasio, 2010, pp. 130-153, p. 175 and pp. 212-215) . What we know as memory, imagination and thinking are in fact all variations of

this arrangement, as the dispositional networks are able to manipulate and rearrange bits and pieces of the maps stored in the early sensory cortices and present them in the form of new thoughts and ideas. As the dispositional networks are unable to produce maps, their operations remain outside consciousness, and so do the basic operations of remembering, thinking and imagining. Depending on the activation of this system, the awake mind will slide between states of pure core consciousness and core consciousness with autobiographical consciousness added.

12.3.03 Externalisation

The machinery behind the autobiographical self is a framework for handling a large amount of memory content in a very flexible and dynamic way; memory content that for the most part will have been acquired through the senses rather than being innate. However, the fact that the processes of thinking, imagining and remembering basically rely on the same machinery as the senses allows for externalisation of memory. By this, external content capable of entering into the process either for its emotional, conceptual or thought related content can be stored externally and communicated between individuals even across generations (Damasio, 2010, p. 290). The possibility for storing and sharing externalized memory content has given rise to phenomena such as the arts, religious rituals and myths, philosophy and science. In other words, the fact that the machinery responsible for the advent of autobiographical consciousness is a flexible framework rather than a fixed set of action programs, allows for the appearance of the dynamic phenomenon of culture. As the autobiographical consciousness is so dependent on the memory content available, the possibility of a development of human consciousness not dependent so much on biological evolution but rather on cultural development prevails (Damasio, 2010, pp. 288-289).

12.4 Architecture

As it might be apparent, the question at all levels, from the basic life regulatory mechanisms and emotions to the content of consciousness, is about how the organism as a biological entity interacts with the world in a way that promotes homeostasis. For the organism, this is a question of handling the conflict between its interior and its exterior, in

order to sustain its homeostatic balance. Architecture can now be seen as a kind of “externalised homeostatic defence”, an extra membrane formed by the building envelope, placed between the skin, the outer boundary of the organism itself, and its environment. By constructing an artificial, controlled environment, the challenge of keeping the balance in the body's inner environment is greatly diminished. To a certain extent, the building envelope and the space it contains come to form an integrated system with the organisms in it.. An architecture understood in this way will be mirroring the basic homeostatic challenges to the organism that in the end hold its reason to be constructed. The implication will be an architecture of the dialectic between the stability of the interior and fluctuation in the external environment. It might add an existential layer to the old, otherwise formal remark of Robert Venturi: “Since the inside is different from the outside, the wall - the point of change - becomes an architectural event. These interior and environmental forces are both general and particular, generic and circumstantial. Architecture as the wall between the inside and the outside becomes the spatial record of this resolution and its drama” (Venturi, 1977, p. 86).

By which means then will the building envelope carry its meaning? Just as consciousness has turned out not to be monolithic, so has the concept of architectural meaning, as architecture will influence the organism at many distinct levels from the simplest life regulatory mechanisms to autobiographical consciousness. By this, architecture mirrors the structure of the organism itself.

12.4.01 Architecture and Basic life regulating mechanisms

Temperature, content of oxygen and carbon dioxide in the blood, air humidity; these are the simple things taken care of by heating, cooling and ventilation devices, either automated or manual. These basic life regulatory mechanisms are mainly about easily measurable amounts of e.g. oxygen, but as oxygen and other necessities are measured within the body, they are not as such connected to any direct perception of the environment. Though architecture influences this, it is merely indirect. Nor can it be said, that these basic life regulatory mechanisms produce any systematic representation of the environment.

12.4.02 Architecture, emotions and feelings

As the task of emotional action programs is to adjust the organism to the environment in order to enable it to cope with actual or anticipated disturbance of the homeostatic balance, it must be expected that emotional action programs are played out as a reaction to either the envelope itself or what is going on in the space created by it. As the emotional system seems to build its appraisal on the totality of events and environment (Barret and Kensinger, 2010; Pessoa, 2011), the building envelope will always be responsible for a part of the reaction. Because these action programs are “largely automated” (Damasio, 2010, p. 109), it must be expected that they, to a certain extent, are predictable both concerning what triggers them and what the resulting bodily and behavioural reaction will be, thus certain architectural patterns or “types” that trigger emotions might be found. It could be speculated that for example the architectural archetypes of Aldo Rossi (Rossi, 1982) or the pattern language of Christopher Alexander (Alexander, 1979) in fact refer to basic emotional behavioral patterns fused into architectural culture. Interestingly, as the task of emotional reactions is the adjustment of the body, the result might be a predictable bodily adjustment to space and envelope design. As emotional programs operate at a non-conscious level, subjects might not be directly aware of the reaction or that it is related to architecture, at all. As the emotional systems work very fast, the result of their reaction might be felt instantaneously.

The changes made to the body and brain state by the emotional action program will be mapped by other structures turning up in consciousness as a feeling. However, as Damasio writes: "Consciousness offers a direct experience of mind, but the broker of the experience is a self, which is an internal and imperfect constructed informer rather than an external, reliable observer” (Damasio, 2010, p. 177).Thus the precise cause of events might not be perceived. Perhaps these feelings are rather what Zumthor refers to when he writes: “I enter a building, see a room, and – in the fraction of a second – have this feeling about it. We perceive atmosphere through our emotional sensibility – a form of perception that works incredibly quickly, and which we humans evidently need to help us survive” (Zumthor, 2012, p. 13), or Gernot Böhme when he writes: “Perception is basically the manner in which one is bodily present for something or someone or one’s bodily state in an environment. The primary “object” of perception is atmospheres.” (Böhme, 1993),

where the perception of the “object” that produces the atmospheres eventually might by the perception of one’s own body state that accompanies the emotional reaction to the perception of the object.

In chapter 5, the definition of architecture by Le Corbusier: “You employ stone, wood and concrete, and with these materials you build houses and palaces. That is construction. Ingenuity is at work. But suddenly you touch my heart, you do me good, I am happy and I say: “This is beautiful.” That is architecture. Art enters in.” (Le Corbusier 19271978, p.141) was rejected on the grounds that it was too imprecise. It is now clear that if it is desired to create a definition of the architecture that distinguishes between general construction and architecture, Le Corbusier’s definition is perfectly useful, if it is understood as a definition of architecture by its ability to create a felt emotional impact in most people.

12.4.03 Architecture and the core self

Via modification of the non-conscious proto-self, the conscious core self is changed as well. By this the experience of the environment becomes part of the self-process. In the case of architecture, the artificial, built, deliberately designed environment is fused into the self. This means that in the case of architecture, the strange situation of a “environment-loop” comes into being, as a supplement to the body-loop underlying the connection between emotions and feeling: 1) The artificial environment in terms of architecture is constructed consciously 2) The emotional system reacts to the artificial environment 3) The reaction is registered as a feeling. Because of the vagueness of the process, the feeling might or might not be directly ascribable to particular properties of the environment by subjects, but rather be experienced as an atmosphere. 4) The feeling state becomes a part of the self. In most cases the architectural environment will not be designed by those it influences. It will be stationary and unchanging and thereby holds the potential to influence emotional - and self-processes in those who reside in it, over longer periods of time. The fact that it to a large extent works by non-conscious processes which not necessarily will be ascribable to the architecture by those who it influences, bears witness to the almost frightening potential power of architecture.

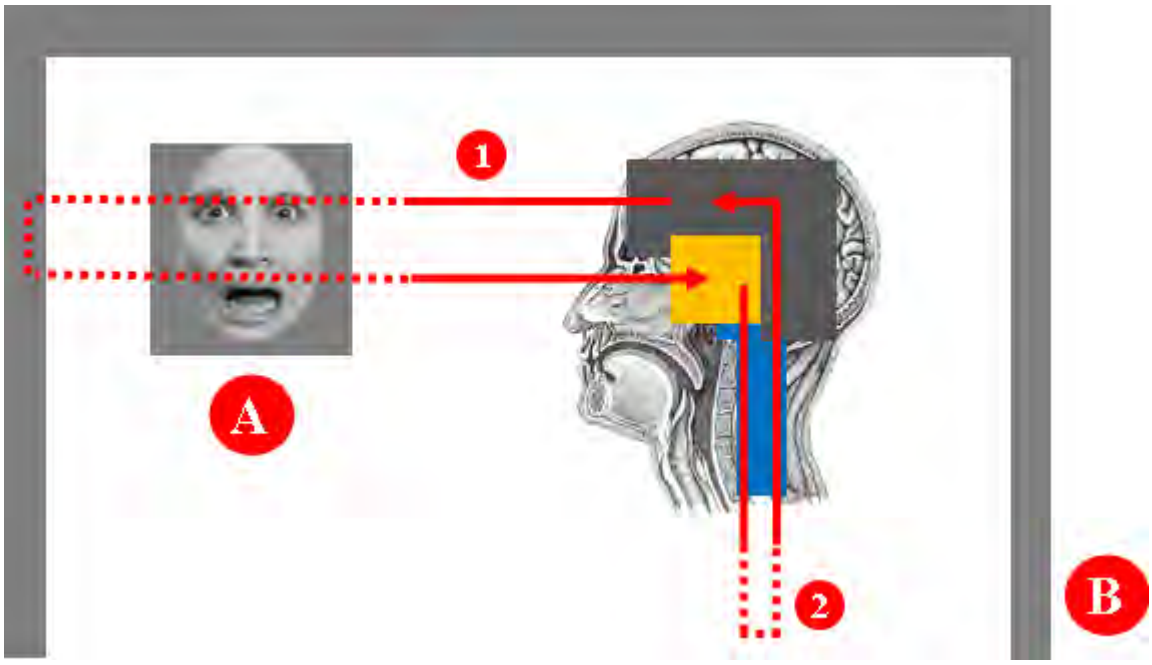

Fig. 12.3. Just as the connection between emotions and feelings works via an internal "body-loop", part of the self-process might work via an external "environment-loop". The following sequence of events could be imagined:
1) an artificial environment is consciously created as an externalized homeostatic defense line. Thus the design of the building envelope ***B*** *affects the emotional system through the "environment- loop".*
2) The emotional system adjusts the body either in direct reaction to the design ***B*** *or as a reaction to emotional events* ***A*** *taking place in the space. The emotional effect of emotional event + envelope is non-consciously experienced as integrated parts of the self through the "body-loop"*

In the above described model, the architectural environment and events taking place in it are appraised by non-conscious, sub-cortical structures, as an entity. It can be speculated, whether the combination of strong, emotionally charged experiences in the form of e.g. religious or political rituals combined with spectacular architectural environments that

have been used by religious and political organizations throughout history, makes use of exactly these mechanisms to assert influence on the emotional state and selves of people, on a mass scale.

Religious rituals systematically repeated, consisting of music, rituals, guided movement etc. in a wide spread system of architectural more or less standardized architecture like churches or temples might ensure an emotional alignment, which on the one hand might hold together a society which does not have alternative means to do so, like it perhaps was the case for example throughout the middle ages, but on the other hand reveals architecture as a formidable instrument of power (see fig. 12.4).

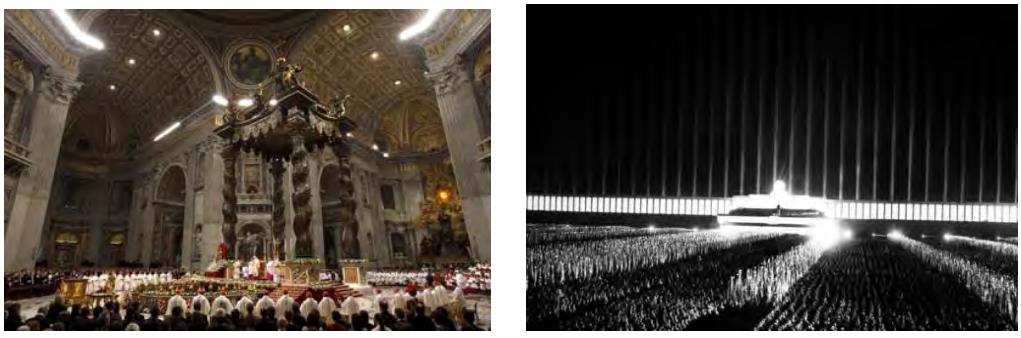

Fig 12.4. Two otherwise incomparable advents, demonstrating the exercise of religious or political influence by the combination of emotionally charged scenes and spectacular architectural environments: A Midnight Mass in St. Peter's in Rome and the Nazi party rally in Nürnberg in 1937.

12.4.04 Architecture and the autobiographical self

Architecture can create and hold externalized memory as related to the senses as combinations of visual content, light, smell, touch, sound, color and patterns of movement. It can thereby be the carrier of culture and collective memory even across generations. The design of space and envelope can thereby create memories that become part of the stock of content making up the thought, memories and imagination of

individuals. As an example, one can dwell on what the importance of patterns of movement has meant during the history of architecture see (fig. 12.5).

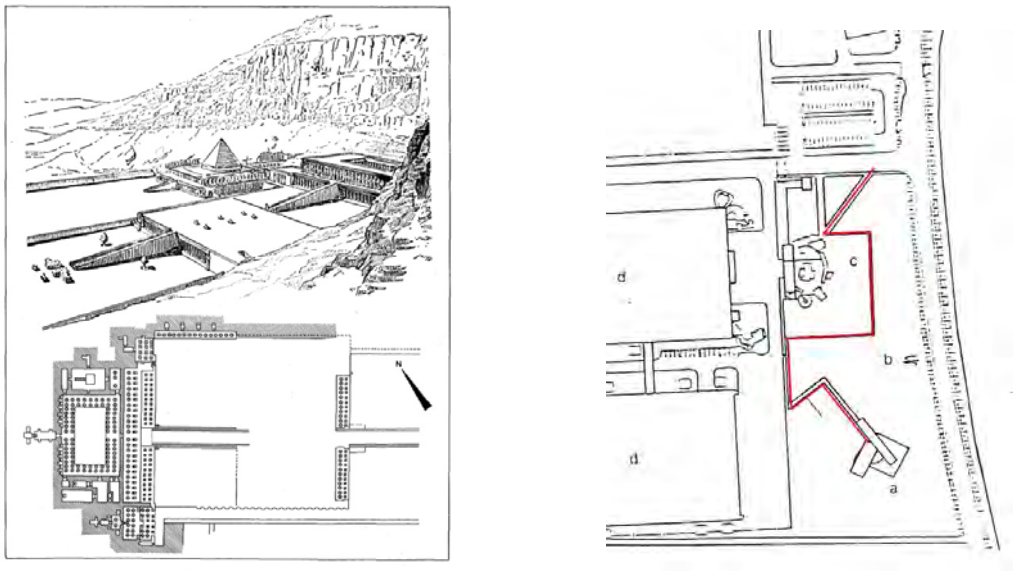

Fig. 12.5 Examples of how movement as potentially a strong part of a memory-complex has been used in architecture. To the left the monumental axial step-wise upward movement of the Mortuary temple of Hatsheput, Deir el-Bahari, Egypt (1511-1480 BC.) (Norberg-Schulz, 1980). To the right the twisted pathway (marked in red) from the parking lot to the Vitra Conference and study center at Weil am Rhein by Tadao Ando (1993).

The envelope can be the holder of symbols, like prehistoric cave paintings, the south-east wall in Le Corbusier's Norte-Dame du Haut at Ronchamp or the overpowering amount of commercial symbols at the Las Vegas strip (see fig. 12.6) or as stated by Pallasmaa: "…the art form of architecture does not only provide a shelter for the body, it also redefines the contour of our consciousness, and it is a true externalisation of our mind…..As we construct our self-made world, we construct projections and metaphors of our own mind scape." (Pallasmaa, 2012, p. 20).

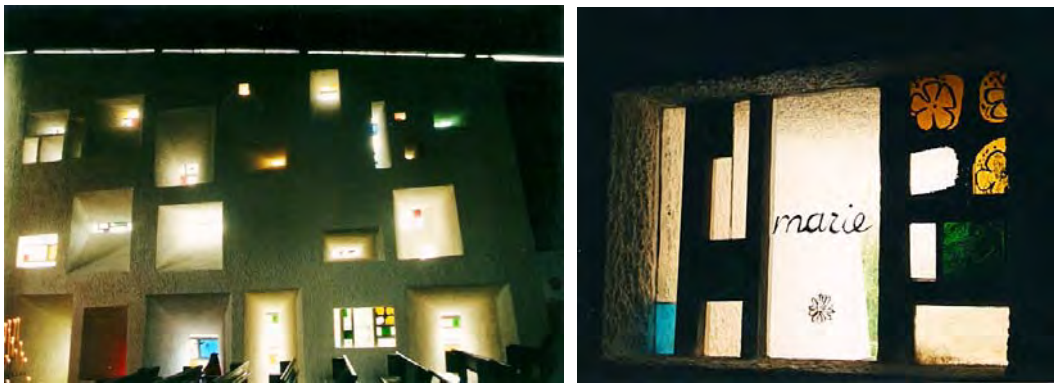

Fig. 12.6 The the south-east wall in Le corbusier's Norte-Dame du Haut at Ronchamp. An example of an bouilding envelope that holds a complex symbolic meaning, which potentially will be externalised to thosewho enters the space

12.4.05 Constructing architecture

In chapter 7 "A historical overview of the search for positive knowledge in architecture", the theory of Laugier was examined. It was shown that, by taking human physiological needs as a point of departure, he introduced a model describing architecture, its elements and the compositional relation between them: a) construction as the prerequisite, b) the building envelope as the means to mediate between the interior and the surrounding environment, c) and the human body as the defining cause. Laugier's ideas of the needs defined by the human physiology were of course very primitive. However, the examination in this chapter taking a modern physiological point of departure by the homeostatic balance has suggested quite another view on the complexity of the human organism and its relationship to the environment. If Laugier's model is confronted with this modern and all-encompassing view, the result might be quite different.

Laugier's main concern in terms of architectural composition was its structural elements, perhaps due to historical circumstance, perhaps because structural problems seemed the most complex at the time. However, an immediate consequence of 'updating' the physiological driven part of the model is that focus is diverted from the building's structural members towards the envelope as main carrier of meaning, as it is the envelope

that directly relates to homeostasis. It suggests that architecture through the senses can be a carrier and creator of externalized content of memory and consciousness. It adds to the understanding of architecture as a carrier of human culture. It suggests that much of our transaction with architecture takes place outside the realms of consciousness, and in this way the experience of architecture perhaps first and foremost involves the body. It suggests that architecture through these non-conscious processes has a profound though somewhat entangled influence on self and consciousness. It emphasizes the dialectic tension between interior and exterior as the architectural advent. Architecture becomes more the act of enveloping than the act of construction.

The driving force behind the architectural drama of the envelope is exactly the contrast between the homeostatic demands that define its interior and the forces of the exterior environment. It must be an architecture that is equally aware of the interior and the exterior. Thus awareness of the building's context culturally as well as climatically is as important an understanding as that of the organisms residing within it, in order to administer the transactions between the inside and the outside. As Gaston Bachelard wrote: “Behind dark curtains, snow seems to be whiter. Indeed, everything comes alive when contradictions accumulate”(Bachelard, 1994, p. 39).

12.5 Conclusion

Through the analysis in this chapter, three possible levels of theory have been identified, as possible routes ahead.

- A theory of how architecture influences the emotions, and thereby influences all aspects of the emotional action programs elicited by the architecture itself, and by events taking place in architectural space. Of special interest in the context of this thesis is of course the emotional system's direct regulatory role in relation to homeostasis.

- A theory of how architecture through the “environment-loop” can influence and include the self.

- A theory of how architecture through externalization can influence the content of autobiographical consciousness and externally held memory content, even across generations.

As the purpose is to find a way in which architecture possibly can influence homeostasis, the obvious choice for further theoretical development must be emotions, due to their direct relationship with the homeostatic balance. As emotions with their close relationship to homeostasis must be seen as a subset of systems that influence health, healing and well-being, a delimitation of the initiating research question, illustrated in fig.12.7 can now be made:

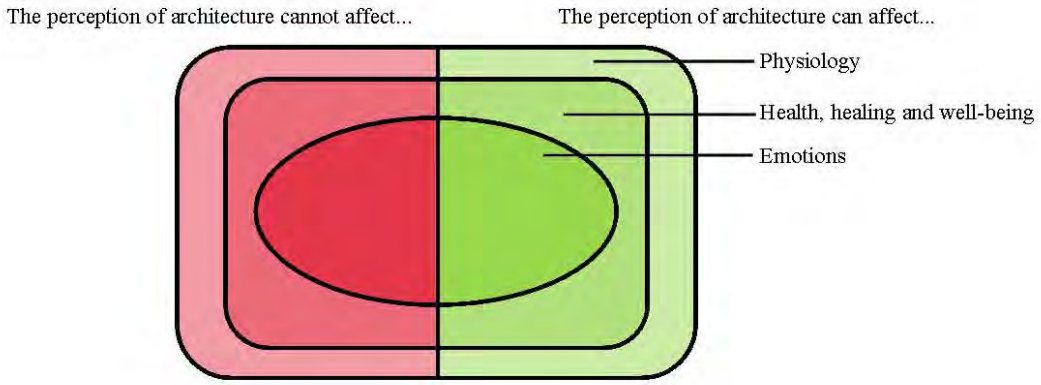

Fig. 12.7 As emotions with their close relationship to homeostasis must be seen as a subset of the systems that influences health, healing and well-being a further delamination of the initiating research question, can now be made.

13

Stress

Based on the understanding of emotions discussed in the previous chapter, it is argued, that stress should be selected as the topic for further inquiry. As stress was just one of the possible mechanisms that were identified in chapter 9 "state of the art", the other two, the placebo effect and distraction, is however also briefly discussed and evaluated. Thus the aim of this chapter is to formulate a theory of how architecture by influencing stress, can affect health, healing and well-being. As a point of departure, a precise definition of stress is established, and as a foundation for the formulation of the theory, the human stress system is reviewed, in order to understand what triggers stress and which effects are to be expected. Finally, the link between stress and immune systems is briefly reviewed in order to establish an understanding of how it can possibly be affected through influencing the stress system. On the basis of this, a theory will be formulated, of which an attempt to falsify it will be made in the following chapter through empirical testing.

There is no single, generally accepted definition of stress. Rather there is what Manson has described as an “almost chaotic disagreement over its definition” (Manson, 1975a, p.6). As a response to this situation, Manson concludes that the only way to avoid confusion is, whenever researchers use the term stress, they should “choose individually to define it” (Manson, 1975b, p.34). As it has been established that homeostatic regulation is a central concept in this inquiry, consequently a definition that is based on the relation between stress and homeostasis must be sought for. Several understandings of precisely what stress apparently exist, and the question must therefore be if any of the generally accepted definitions covers this criteria. However, a frequently used definition within research in stress from a physiological point of view (Ulrich-Lai and Engeland, 2005; Ulrich-Lai and Herman, 2009) is: “The term “stress” describes a state of threatened “homeostasis”” (Chrousos, Loriaux and Gold, 1988, cited in Johnson et al. 1992). Stress

seems to lie at the heart of what can be termed emotional reactions. In the last chapter it was further discussed what actually is encompassed by homeostatic regulation, and it was concluded that: “Emotional systems should be viewed as systems that , through the appraisal of a situation, are able to address a threatening imbalance in advance through the implementation of preparatory actions”. Thus the very example chosen by William James to explain and define emotions, the story with the bear in the woods, is in itself an example of a stressful event. Furthermore, stress by the definition used here, is very closely related to homeostatic regulation. For this reasons, the stress mechanisms is chosen as physiological systems that is chosen for further investigation.

However, as two other possible mechanisms was identified as possible mechanisms in chapter 9 “state of the art”, namely distraction and the placebo effect, they will be briefly discussed, to ensure that the choice is well informed.

13.1 Distraction and the placebo effect

Distraction refers to techniques such as “hypnosis, behavioral modification, relaxation training, biofeedback, operant conditioning and cognitive-behavioral therapy that can change the manner in which an experimental subject reports the occurrence of a painful stimulus” (Miron et al. 1989). The main instrument to manipulate the pain experience is manipulation of attention (Miron et al. 1989; Villemure and Bushnell, 2002). Thus distraction clearly is about the conscious experience of pain, as it is brought about through the manipulation of one of the elements of consciousness, namely attention. Distraction must therefore be disregarded in the context of this inquiry on these grounds, as the inquiry has been delimited to the non-conscious emotional bodily regulations of homeostasis, ruling out the conscious experience of these regulations.

As established in 9 “State of the Art”, Sternberg has proposed the placebo effect as a possible link between architecture and healing effects (Sternberg, 2001, pp. 159-180; Sternberg 2009, pp. 193-214). The placebo effect is potentially a powerful effect, demonstrated in meta-study by Henry K. Beecher in 1955. Beecher showed that on average the placebo effect was responsible for over 30 percent of the effect of medicine, in general. Beecher even showed that like other therapeutic agents, placebo can have toxic side effects. The fact that Beecher apparently had demonstrated an overall effect of

about 30 percent meant that this almost assumed the character of a rule. However, several studies have later showed that the 30 percent are not consistent for all treatments, some being considerably under and some over (Vallance, 2006). Five prominent hypotheses exist about the mechanisms behind the placebo effect, namely: “Anxiety reduction”, “Expectation”, “Transference”, “Meaning effects” and “Conditioning”(Vallance, 2006). Sternberg has proposed that the two most well described, “Expectation” and “Conditioning” are in fact one and the same effect, which can be responsible for the possible healing effects of architecture (Sternberg, 2009, p. 199).There are several definitions of the placebo effect. While some are specifically related to the use of placebo in placebo controlled medical experiments, Craen et al. (1999) in an overview recommend using Brody’s definition in psychological research. Brody’s definition of the placebo effect is: “The placebo effect is the change in the patient’s condition that is attributable to the symbolic import of the healing intervention rather than to the intervention’s specific pharmacological or physiological effects” (Brody, 1982). Basically, Sternberg’s argument is that the “symbolic import” can be a specific place or specific features of a place. Ader and Cohen have shown that the immune system can be conditioned (Ader and Cohen, 1975; Ader and Cohen 1980; Ader, 2002). In the experiment by Ader and Cohen referred to by Sternberg, mice with an autoimmune disease called systemic lupus erythematous were used. Systemic lupus erythematous is a life threatening condition if not treated, in which the immune system attacks the body and causes inflammation in several organs. As it is a disease in which the immune system attacks the body itself, the treatment is an immune suppressive drug. The mice were then treated with the immunosuppressive drug, and some of the mice were conditioned to associate the administration of the immunosuppressive drug with administration of saccharin-sweetened water. After the training, the antibody levels decreased (the immune system was suppressed) in the conditioned mice when receiving only saccharin-sweetened water, while mice in the control group which had not been conditioned, died when only receiving saccharin-sweetened water (Sternberg, 2009, pp. 200-202). It has later been shown that the immune system can be conditioned in humans as well, in an experiment by Goebel et al. (2002). fMRI and PET scanning experiments have pointed to the reward and expectancy system in the brain, centered on the nucleus accumbens (NAC) (Scott et al., 2007). As the NAC administrates the release of the neurotransmitter dopamine (DA) which has led to research into Parkinson’s disease, as it gradually

destroys the dopamine pathways (Fuente-Fernández et al., 2004; Fuente-Fernández, 2009). Sternberg argues that the expectations can be established through conditioning or through the imperceptible learning from everyday experience; it is either a personal experience or tied to culture, e.g. the conception that drug-like capsules heal can work as placebo in cultures, where capsules are generally associated with healing. Furthermore, it is established that animals can be conditioned to a place, e.g. animals that are conditioned by rewards in a particular part of a maze, will spend more time there also when not rewarded (Bardo and Bevis, 2000). Thus Sternberg argues that as placebo has to do with conditioning "these animal studies suggest that people who have learned to associate a place with a positive feeling – or with hopes that the place will heal – will benefit from simply being in that place. Some of the beneficial effects of such places that promote healing might come in part from the same brain pathways that are activated during the placebo effect – the dopamine reward and opiate endorphin pathways." (Sterberg, 2009, p. 199). However, although this is an interesting hypothesis, it does not relate to architectural qualities, as the presumed immune response through conditioning could potentially be tied to any recognizable place, regardless of its architecture. Furthermore, reactions learned through conditioning cannot be said to qualify as"..automated programs of actions concocted by evolution" (Damasio, 2010, p. 199) and thereby not be defined as emotions. The fact that learned responses will not necessarily be generalizable between individuals will make it difficult to find architectural features that in general will be connected with an effect. It should however be noted that people living in cultures with strong collective symbols carried by architecture will probably also have formed architectural types associated with conditioned effects of one sort or another. This could provide a link between the possibilities of externalization and physiological influence through conditioning. However, the mechanism that governs the interaction between the nervous system and the immune system in the placebo effect still does not seem to be well understood, as Ader (2003) writes: "At present, little is known about the mediation of conditioned immune response…. Presumably, the mechanisms involve the autonomic nervous system and/or neuroendocrine processes plus feedback regulation by the immune system. Furthermore, it is likely that different pathways support the development and/or expression of different alterations of different immune responses, i.e., there is probably no single pathway that can account for the observed effects". Thus the objective stated in chapter 9 of reaching an understanding of how the built environment might or might not

influence health, healing and well-being that includes an understanding of the underlying physiological mechanisms, can hardly be reached based on the current understanding of the placebo effect. Although the placebo effect through its effects on the immune system clearly is related to homeostasis, the uncertainty of the mechanisms that drive it also makes the understanding of this relationship difficult.

13.2 Stress

Historically the concept of stress stems back to the beginning of the 20th century, and has gradually changed and developed along with the growing knowledge of psychology and physiology. In 1914 Walter B. Cannon proposed an instinctive fight-or-flight behavior controlled by the sympathetic nervous system as response to fear, anger or rage. He further described the mobilization of stored energy resources necessary for such a behavior "at times of stress". In his 1929 paper on homeostasis, he further associated the stress reactions of the sympathetic nervous system with the maintenance of the homeostasis (Cannon, 1929; Manson, 1975; Fleming, 1984). In 1936 the Canadian endocrinologist Hans Selye (1907-1982) who, in an attempt to find a new sex-hormone injected various compounds into rats, noted that the physiological response was the same regardless of the type of compound he injected. He then exposed rats to other types of physical strains, and noticed that the reaction was still the same. As he thought the reaction he had observed was the reaction of the organism to any physical challenge, he proposed a theory of what he termed the 'general adaptation syndrome' (GAS) (Selye, 1936; Manson, 1975; Sterberg, 2001, pp. 59-66). In 1946 he introduced the term stress meaning the outside force acting on the organism to trigger GAS (Manson, 1975). Although stress began as the study of physical strains, it soon became clear that psychological factors could trigger the physiological stress response just as well, and that psychological factors often had a stronger impact than physical stressors. In 1973 Selye wrote: "It is difficult to see how such essentially different things as cold, heat, drugs, hormones, sorrow, and joy could provoke an identical biochemical reaction in the organism. Yet this is the case" (Selye, 1973). In accordance with this, Selye redefined stress as "the nonspecific response to any demand" by an organism (Selye, 1973; Selye, 1975). Research in stress rapidly spread within physiology as well as psychology, as previously mentioned resulting in an "almost chaotic disagreement over its definition"

(Manson, 1975a, p.6) whiche made Manson concludes, that the only way to avoid confusion is that whenever researchers use the term stress, they should “choose individually to define it” (Manson, 1975b, p.34).

In accordance with the distinction between emotional action programs, which account for substantial bodily adjustments, and feelings in the form of a perception of these adjustments (Damasio, 2010, p. 109), a clear distinction must be drawn between stress as emotion and stress as feeling. It is therefore essential to clarify whether an inquiry into stress is related to stress as an emotion, or if it is about stress as feeling or perhaps about the relation between the two. As noted by Damasio: "Consciousness offers a direct experience of mind, but the broker of the experience is a self, which is an internal and imperfect constructed informer rather than an external, reliable observer” (Damasio, 2010, p. 177). Thus we cannot expect that the conscious feeling of stress makes a reliable account for whether an emotional stress-action program is activated. In a small meta-study of the association between measures of self-reported mental stress and saliva cortisol (a stress hormone; see below) at the work place, Hjortskov et al. (2004) found that two studies (13 per cent) reported a negative association, four studies (27 per cent) reported a positive association and eight (60 per cent) reported no association. This might however be due to methodological differences between the studies reviewed, as the authors note in their discussion. The authors conclude that a straight forward link between physiological stress and experienced stress may not exist. In an analysis of 358 studies which all included self-reported stress as well as cortisol measures in a standard laboratory stress test called the Trier Social Stress Test, Campbell and Ehlert (2011) found only significant correlations between physiological stress and perceived stress in 27% of the studies.

In this thesis, in which health is associated with the proper management of the homeostatic balance, the choice must obviously as previously discussed be, to investigate stress as an emotion and not as feelings, as the essence of emotions is management of homeostasis. The most appropriate must therefore be to choose a definition of stress that is closely related to the homeostatic balance as basis for the inquiry such as the well-recognized definition by Chrousos, Loriaux and Gold, which is well established in

physiological stress research (Chrousos, Loriaux and Gold, 1988, cited in Johnson et al. 1992):

- "The term "Stress" describes a state of threatened "homeostasis".
- "The threatening, disturbing forces are defined as "stressors".
- "The counteracting forces put forth to neutralize the effect of the stressors and reestablish homeostasis are called "adaptive response".

Furthermore, stress can be divided into two types (Ulric-Lai and Herman 2009):

- 'systemic stress', which is a threat to homeostasis that requires an immediate 'systemic' reaction such as blood loss, infection or pain.
- 'psychogenic' stressors which constitute reaction to anticipated threats to homeostasis based on prior experience or innate programs.

In both cases, the aim is to minimize disturbance to homeostasis through adaptive behavior. It is important to note that stress is basically a healthy adaptive behavior that might become maladaptive or directly harmful, when it appears in a context for which it was not developed by evolution, which can happen, if the stressor does not disappear despite the adaptive behavior that was supposed to eliminate it (Kloet, 2002). This can frequently happen, when innate and rather stereotypic emotional action programs of stress are launched by situations typical of the modern society, for which they were not developed. An adaptive stress reaction can be launched as a result of data received from all major sense modalities. *Interoceptive* sense data is mainly about systemic stress e.g. threats to homeostasis such as changes in blood volume or infections, while *exteroceptive* sense data could be such as the smell of a predator as well as more complex threats, such as social situations which potentially might threaten the individual's position within the social hierarchy, and thereby the access to resources. In both cases an interpretation of the situation is needed before action can be taken, though the appraisal of exteroceptive sense data in situations of psychogenic stress will need a much more complex appraisal process than simple reflexive reactions to e.g. haemorrhage. The neural and neuroendocrine systems in the brain that are recruited to enable the adaptive behavior, and thereby minimize the net cost for the organism, is called *stress effectors* (Ulrich-Lai and herman 2009).

13.3 Stress effector and trigger systems

The stress management system in the body is composed of two major and to some extent overlapping *stress effector* systems, namely the autonomic nervous system (ANS) and the Hypothalamo-Pituitary-Adrenocortical (HPA) axis (Ulrich-Lai and Herman 2009). The ANS consists of two sub-systems: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS is within seconds able to increase heart rate and blood pressure, while PNS reflexive activity is capable of terminating it even quicker. The SNS is present in the adrenals, and this connection constitutes the sympathetic- adrenal-medullary (SAM) system, which controls the release of the hormones adrenaline and epinephrine. In addition, sympathetic nerves all over the body can release the adrenaline-like hormone nor-epinephrine, (Sternberg, 2001, p.110-112; Herman et al. 2003; Fulford and Harbuz, 2005, p. 43; Ulrich-Lai and Herman, 2009). The other major system, the HPA-axis, works mainly through the endocrine system. Corticotrophin releasing hormone (CRH) is released from the hypothalamus in to the bloodstream, stimulating the release of adrenocorticotropic hormone (ACTH) from the pituitary, which in turn elicits the release of the HPA-axis' end product glucocorticoid hormone, of which the human version is called cortisol, from the cortex of the adrenals. The result of the action of the HPA-axis is profound and wide spread throughout the organism, as a majority of the body's cells has cortisol receptors. Among its effects is the regulation of digestion, blood sugar and the immune system (Buckingham 2006; Dedovic et al., 2009; Herman and Cullinan, 1997; Herman et al. 2003; Herman et al. 2005; Herman and Mueller, 2006; Dedovic et al. 2009; Ulric-Lai and Herman, 2009). There is a diurnal rhythm of cortisol concentration in the blood which in both genders is highest in the morning just before awakening and decreases during the day. The concentration is age dependent and in women the variation is dependent on the stage of the menstrual cycle as well, thus cortisol release due to stress must be considered a deviation from this standard curve (Kudielka et al., 2004; Fulford and Harbuz, 2005, p.45). The level of cortisol regulates itself through a negative feedback loop, as it binds to receptors in the hypothalamus itself as well as in a number of limbic structures such as the hippocampus (HC), amygdala (AMG) and prefrontal cortex (Dedovic et al. 2009; Sternberg 2001, p. 58; Herman and Cullinan, 1997; Herman et al. 2005). The hypothalamus which controls the HPA-axis is an extremely complex organ that is partly a gland and partly a brain

center, and as such is the structure that constitutes the bridge between the nervous system and the endocrine system. Besides this, it is responsible for a waste amount of body surveillance, regulatory tasks and instinctive behavior (Hart, 2006, p.130). The triggering sites of adaptive behaviors to systemic and psychogenic stress are not the same, although to some degree they overlap. Systemic stress is triggered mainly from nuclei in the brainstem, receiving signals about homeostatic disturbances such as blood loss, respiratory distress, visceral or somatic pain or inflammation, but can also be launched from the AMG (Ulrich-Lai and Herman 2009). In comparison to systemic stress, psychogenic stress whose purpose is to predict and avoid possible threats to homeostasis requires a much more complex processing. This is done by a complex interplay between multiple structures in the limbic forebrain, of which the main structures is the AMG, the HC, the prefrontal cortex (PFC), ventral subiculum (vSUB) and the periaqueductal gray matter (PAG). The AMG is considered the excitatory site among the limbic structures and consists of a number of sub-nuclei with different roles in stress activation. The central nucleus (CeA) reacts to systemic stressors and is weighted towards autonomic stress response rather than the HPA-axis. In contrast, the medial (MeA) and basolateral (BAL) nuclei are primarily activated by psychogenic stressors, and are mainly associated with activation of the HPA-axis (Herman et al. 2003; Herman et al., 2005; Ulrich-Lai and Herman 2009). The HC and the vSUB exert a mainly inhibitory influence on HPA-axis response to psychogenic stressors and form part of a feed-back loop. The HC is a complex organ which combines the creation of memories about facts and knowledge with spatial navigation, suggesting its role in stress regulation. Patients with lesions that have destroyed the HC in both sides of the brain have their capacity to form and hold new memories restricted to about one minute (Beecher & Milner, 1957; LeDoux, 1999, pp. 182-186; Damasio, 2000, pp. 117-121). Besides forming memories, the HC holds a cognitive map of the surroundings. Distant landmarks, local clues as well as recordings of movement are used to locate the animal within the map (O'Keefe and Dostrosky, 1971; Shapiro et al. 1997, Sharp, 1999). Non-spatial information is tied to specific positions on the map in the form of so called "placefields", thus it appears, quite interesting from an architectural point of view that the cognitive map is the underlying code of memory (Sharp, 1999). The map is generated and fed into the HC by two adjacent structures, the subiculum (SUB) that tracks place x direction x motion, and the entorhinal cortex (EC) which holds a set of general maps which are adapted to the actual setting by the HC as

information becomes available. Of special interest from an architectural point of view, Sharp (1999) has proposed that these general maps are "trained into the system during development, as a result of experiences the young animal has in a stable environment", meaning that if the model is correct and can be transferred to humans, we basically navigate adapted versions of our childhood home throughout life. Of special relevance in the context of this thesis, the HC is involved in encoding and learning processes concerning space boundaries (Doeller and Burgess, 2007; Doeller et al. 2008), as the idea was developed in chapter 12 that the architectural emphasis must be on the building envelope/space boundary. Much of the knowledge of especially the HC's role in spatial navigation is obtained in animal experiments, but perhaps as a kind of confirmation, Hassabis and colleagues in 2009 managed directly to read the cognitive map in the human HC using fMRI scanning (Hassabis et al. 2009). The Prefrontal Cortex (PFC) is the least understood of the structures involved in triggering and managing psychogenic stress. Studies of cases of injuries to the PFC in humans by Damasio and colleagues indicate that it is involved in learning of complex social behavior and behavioral rules, and by that being involved in impulse control by inhibiting other structures (Saver and Damasio, 1991; Bechara et al., 1994; Anderson et al., 1999; Davidson and Irwin, 1999; Davidson, 2000). The brain structure called the periaqueductal gray matter (PAG) consists of three substructures each serving a specific type of coping behavior. Thus, depending on the combination of activation, the choice of coping strategy depends on a) if the stressor is escapable or in-escapable and b) if the stressor is predominantly physical or psychological. Thus escapable physical and psychological stressors will result in an active emotional reaction based on fight-or-flight behavior, while inescapable stressors will result in a passive emotional coping strategy based on a conservation-withdrawal behavior and disengagement from the environment. The three substructures of the PAG react on the basis of signals they receive about the current homeostatic state from the spinal cord and on descending information from the hypothalamus and the PFC (Parvizi and Damasio, 2000; Keay and Bandler, 2006). Furthermore, the PAG might be involved in the management of the process related to whether stress as an emotion ends up as a conscious feeling. On their way from the body to the insula, signals that constitute the sensing of the body pass a set of nuclei in the brain stem, the nucleus tractus solitaries and the parabrachial nucleus. Far from being passive relay stations, these nuclei produce a comprehensive picture of the internal milieu and viscera, which happens to be "the prime

component of our feelings" (Damasio, 2010, p.78). Furthermore, they are extensively connected to the PAG which means that coping can come about by the PAG influencing the signal from the body to the insula through its connection to these nuclei (Damasio, 2010, pp.78-80), which might also account for at least some of the dissociation found between emotional stress and stress as feelings.

13.4 The coordinated adaptive response to stress.

When stress occurs, the HPA-axis and the SAM-system provide the organism with the necessary energy resources for adaptive behavior, such as the flight-or-fight behavior. Stored energy resources are released and blood pressure, heart rate and respiration increased. In parallel to this, energy-consuming processes that are irrelevant in connection with the acute situation such as feeding and reproductive behavior, digestion and immune function is shut down (Johnson et al. 1990; Herman et al., 2003; Fulford and Habuz, 2005). However, the adaptive stress response which is energy consuming and inhibitory to several important functions has to be terminated as soon as the stress episode has ended. While the ANS driven response wanes quickly, the HPA-axis response wanes more slowly under the control of a complex feed-back mechanism involving inhibitory structures such as the HC and PFC. Animal studies suggest a division of labor, so that the SAM-system primarily is activated when the animal is confronted with a challenging situation that can be mastered, while the HPA-axis is activated when a sense of uncontrollability occurs (Henry, 1991).

As seen in fig. 14.1, the hypothalamus together with a structure called nucleus of the stria termonalis form a coordinating "middle management" system that disposes the stress response under the influence of 1) the ongoing homeostatic balance, 2) "top-down" signals concerning experiential factors or innate programs (psychogenic stress) or 3) bottom up signals concerning actual homeostatic imbalance such as pain or inflammation (systemic stress). Thus the "middle management" functions determine the distribution between HPA and SAM activation. Contrary to Selye's idea that stress is "the nonspecific response to any demand", the stress response will be adapted to the specific situation, although the mechanism that performs the adaption will be the same.

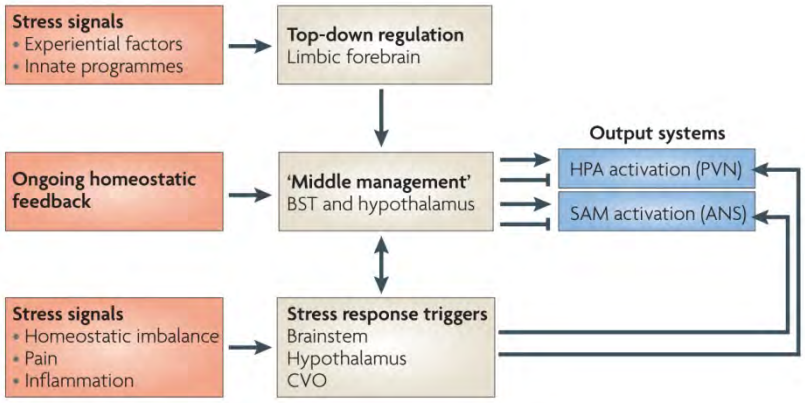

Fig 14.1 The hypothalamus together with a structure called the bed nucleus of the stria termonalis (BST) forms a coordinating "middle management" system, under "top-down" influence of stress signals concerning experiential factors or innate programs (psychogenic stress) or bottom up stress response triggering signals concerning actual homeostatic imbalance, pain or inflammation (systemic stress). This "middle management" function then determines the distribution between HPA and SAM activation.(from Ulrich-Lai and Herman, 2009)

13.5 Interaction between the stress- and immune system.

The body possesses two immune systems. The natural immune system that produces a non-specific reaction and is important in wound healing is able to launch a reaction within minutes. The specific immune system reacts slowly and to reach a full blown reaction of the specific immune system can be a matter of days. The specific immune system responds to specific pathogens called antigens with antibodies that effectively target infections (Denson et al., 2009). Part of the adaptive response to stress is a regulation of the immune response, which depends on the duration of the stress exposure. Acute stress, defined as stress lasting 5 – 100 min. such as stress experiments with stressors like public speech and mental arithmetic (Segerstrom and Miller, 2004) only suppresses the specific immune response and might actually enhance the natural immune system. Experiments with rats infected with coli bacteria exposed to acute stress

compared to unstressed rats indicate that the adjustment to the immune system during acute stress might in some cases be advantageous as the stressed rats overcame the immune challenge significantly faster (Deak et al. 1999). The problem is of course to determine when stress turns from being a generally advantageous adaptive process as acute stress, into a harmful and maladaptive one. Change in the generally adaptive immune regulation of acute stress starts to occur already in what Segerstrom and Miller (2004) terms “brief naturalistic stressors” such as examination stress. Although the most severe consequences will be observed in connection with prolonged and especially chronic stress which has negative effects on almost all functional measures, immune deregulation can be observed even as a result of commonplace daily hassles (Kiecolt-Glaser et al., 2002; Segerstrom and Miller, 2004; Glaser and Kiecolt-Glaser, 2012). Black (2001) has on the basis of a review on autoimmune disease hypothesized that repeated acute psychogenic stress can have the same effect as chronic stress.

The autonomic nervous system is present in the organs which produce immune cells, namely the liver, spleen, bone marrow, thymus and lymph nodes, enabling sympathetic activation to down regulate the production of immune cells (Friedman and Irwin, 1997; Staub et al. 1998; Steinman, 2004). Cortisol has an extensive, largely inhibitory effect on immune cells (Fulford and Harbuz, 2005, p.50). The behavior that in a natural environment would be adaptive might then appear inappropriate or directly harmful. The dilemma of the organisms is largely that resources have to be disposed so that homeostasis can be defended, both on a microbiological level and on the scale of e.g. predators, in the most efficient way. On the microbiological level the organism is subjected to an ever changing load of noxious agents such as bacteria, viruses, fungi, etc. The immune system therefore has to work at a level closely adapted to the actual challenge. If it is less active infections occur, if it is over-active the immune cells will attack the body's own cells and inflammatory/autoimmune diseases will occur e.g. allergic reactions, rheumatoid arthritis or multiple sclerosis. An immune reaction therefore has to be terminated at the exactly right point in the process. An immune reaction is a well-coordinated chain of actions by various types of immune cells. The coordination is performed via molecules called cytokines that carry signals between the immune cells (see fig. 14.2). The termination of the immune reaction takes place when certain cytokines that are present in large concentrations when the immune system is very

active, are detected by the hypothalamus, which then activates the HPA-axis and the SNS, to dampen the activity in the immune system. This means that if the HPA-axis and SNS is over-active because energy resources are prioritized for coping with a stress episode, the immune system will be dampened perhaps below an appropriate level. If especially the HPA-axis is less active, which can happen as a result of prolonged or chronic stress, the immune system might become overactive, resulting in autoimmune disease (Kemeny and Schedlowski, 2007; Glaser and Kiecolt-Glaser, 2005; Steinman, 2004; Segerstrom and Miller, 2004, pp. 2-7; Yang and Glaser, 2000; Elenkov, 2000; Sternberg 39-54, 68-69 and 79-91; O'Leary, 1990). Specific cytokines (IL-1) interact with the brain and produce so-called "sickness behavior" characterized among other symptoms by fatigue and a depressed mood. When autoimmune disease becomes chronic, a constant presence of IL-1, and thereby permanent sickness behavior, can cause depression (Sterberg, 2001, pp. 188-189 and p. 195; Dantzer et al., 2008).

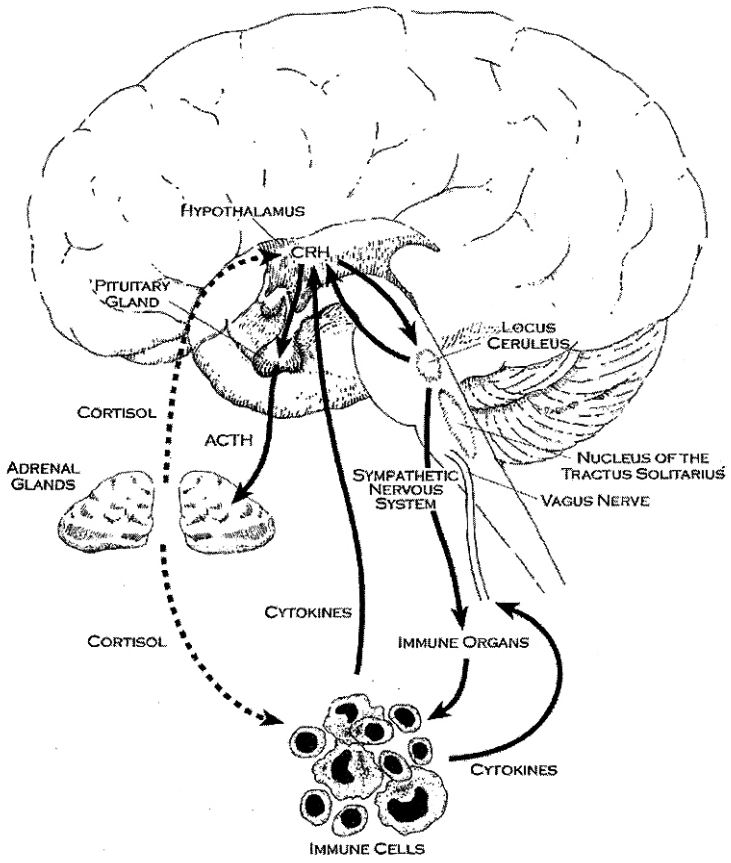

Fig. 14.2. Schematic representation of how the HAP-axis and the SNS interact with the immune system. (From Sternberg, 2001)

Besides the theoretical unraveling of the interaction of the stress systems and the immune system, a great number of studies have empirically demonstrated the existence of such a link. Perhaps the most comprehensive meta-study made is by Segerstrom and Miller (2004) covering approx. 300 studies over a period of 30 years. Though the association between emotional stress and immune regulation is well established, Segestrom and

Miller note that the number of studies actually confirming the theoretical implication of a link between stress and disease is very limited.

Several studies have investigated the possibility of a connection between stress and susceptibility to upper respiratory infections (URI). In a meta-analysis Pedersen et al. (2010) found statistical significant correlation between stress and URI in 10 out of 14 studies of major life events, 2 out of 7studies of minor events and hassles, and 4 out of 8 of perceived stress.

Also, wound healing has been studied. In a study by Marucha et al. (1998), 11 dental students (9 men, 2 women, mean age 24,36) were inflicted with an oral mucosal wound, first in a presumably unstressed situation in mid-august at the end of the summer vacation , and a second time approx. 6 weeks later, 3 days before the first major academic examination. The wounds inflicted in connection with the exam took approx. 40% longer to heal than those inflicted in connection with the summer holiday (7,82 days and 10,91 days respectively). The effect of stress on wound healing has led to considerable attention to- and research in - the improvement of post-surgical wound healing by dampening pre-surgical stress, which has become extremely important as day surgery has been widely used (Kiecolt-Glaser et al., 1998). An intervention that has proved to be effective is music therapy before as well as during the surgery, as local anesthetic is preferred in many instances. Leardi et al. (2007) found that in patients listening to preselected or patient selected music from one hour before surgery until the end of surgery, plasma levels of cortisol as well as natural killer lymphocytes (a type of immune cells) decreased during surgery, but increased during surgery in the control group that didn't listen to music.

In theory stress might potentially be able to influence certain types of cancer. However, despite intense research, it has not been possible to produce convincing and unambiguous evidence that stress may cause or influence the development of cancer in humans, as studies point to diverging or contradictory trends. This might be due to methodological problems. First, cancer does not represent a heterogeneous group of diseases and secondly, the length of time it takes for the disease to develop makes it difficult to decide if psychological factors or other lifestyle-related factors are crucial (Reiche et al., 2004). However, the studies of tumor growth in rats exposed to either inescapable or escapable foot shocks of a duration of max. 60 sec., 60 times over a period of 30 days, demonstrated

that those exposed to escapable foot shock, meaning they were in control, were twice as likely to have rejected the injected tumor cells than those who had received inescapable foot chocks (Visintainer et al., 1982).

13.6. The influences of stress on well-being in which the immune system is not involved

The HC is rich in cortisol receptors, and stress therefore influences memory. While prolonged exposure to stress inhibits memory function as such, a review of fMRI studies in which acute stress, provoked by stressfull films, pictures or by evaluating threatening situations showed that during acute stress encoding of memory is enhanced, but retrieval might be reduced (Kim and Diamond, 2002; Stegeren, 2009). Porcelli et al. (2008) in an fMRI study found that acute stress impairs the working memory which resides in the PFC. An overactive HPA-axis might lead to depression and impaired cognition. It is found that in at least 50% of depressive patients, the HPA-axis is hyperactive, presumably because of an inactive feed-back mechanism (Kloet, 2002).

13.7 A theory of architecture, stress, health, healing and well-being

The major influence of stress on health, healing and well-being has now been briefly reviewed. In the following, a theory of the connection between the perception of architecture and stress will be proposed.

13.7.01 The linking of the stress and the immune system as an adjacent theory

That a clear link between the stress systems and the immune system exists is well established, and changes in the immune system as a result of stress are empirically demonstrated in many studies. However, still only a few studies have examined what these changes mean in relation to specific cases of infection and healing, such as URI infections (Segerstrom and Miller, 2004; Pedersen et al., 2010). Furthermore, the question concerning how the duration of stress or repeated acute stress influences the immune

system needs further development. There is no question that prolonged or chronic stress has an impact on health, but architecture is probably irrelevant to these types of stress, as life-stress episodes like divorces, job-loss or bereavement might not be tied to a particular architectural context. Pedersen et al. (2010) found effects on URI tied to minor life events and hassles, implying that brief stress episodes have an impact as well. The study on wound healing by Marucha et al, (1998) concerned with academic exam stress also points to the effect of brief stress episodes, and might be hypothesized to be in accordance with the study on impact of a view to nature by Ulrich (1984). However, it is characteristic that patients in Ulrich's study remained in the same spatial context in the form of the patient bed room and enjoyed the same view, throughout the process. A crucial question is whether a series of acute stress episodes can have the same effect even as chronic stress, as hypothesized by Black (2001); this seems to be supported by the animal experiment of Visintainer et al. (1982) on the influences of repeated foot shocks constituting a series of separated acute stress episodes, on the ability to reject injected tumor cells in rats. Although all this points to a close interrelationship between the stress system and the immune system, it also is clearly a field that needs more research. The task to establish more empirical understanding of the relationship between stress and the course of specific diseases or healing processes is a massive research task, and will be considered to be outside the range of this thesis. It will therefore be taken as a premise that stress via the immune system can have an impact on infectious diseases, wound healing and autoimmune diseases. The theory that stress substantially influences the immune system will therefore be treated as an “adjacent theory” (See 14.3). It must however be noted that the consequence of introducing an adjacent theory is that the future scientific usefulness of the results will be dependent on the developments which undoubtedly will take place in the field of psychoneuroendocrinology.

13.7.02 Conclusion

Before formulating a theory of the impact of architecture on health, healing and well-being, it might be appropriate to place it within a general methodological framework of this thesis, as outlined in the diagram fig.8.10 in the end of chapter 8. In fig.14.3 below, the theoretical development up until now is illustrated. As can be seen, the task is now to formulate a theory of how architecture can influence stress, assuming that architecture

thereby in addition to the health risks caused by stress itself, can influence the homeostatic processes taken care of by the immune system, as indicated by the adjacent theory of the interplay between the stress systems and the immune system. Furthermore, it must be possible to extract a falsifying hypothesis from the theory. Following Peirce, as he writes: “If nature replies “No!” the experimenter has gained an important piece of knowledge. If Nature says “Yes,” the experimenter’s ideas remain just as they were, only somewhat more deeply engrained.” (Peirce 1903, vol. 2 p. 215) The theory cannot be proved by any empirical test, and as such, theories are only tentative conjectures (Popper 1953, 1974, p. 102). The task will therefore be to put it to a test that potentially can disprove it. The adjustment or rejection of the theory made on the basis of this empirical test or any future tests will constitute scientific progress. To make this possible, the theory must meet the requirements of a falsifiable theory: ”A theory is to be called ‘empirical’ or ‘falsifiable’ if it divides the class of all possible basic statements unambiguously into the following two non-empty subclasses. First, the class of all those basic statements with which it is inconsistent (or which it rules out, or prohibits): we call this the class of the potential falsifiers of the theory; and secondly, the class of those basic statements which it does not contradict: a theory is falsifiable if the class of its potential falsifiers is not empty”. (Popper 1934, p.150).

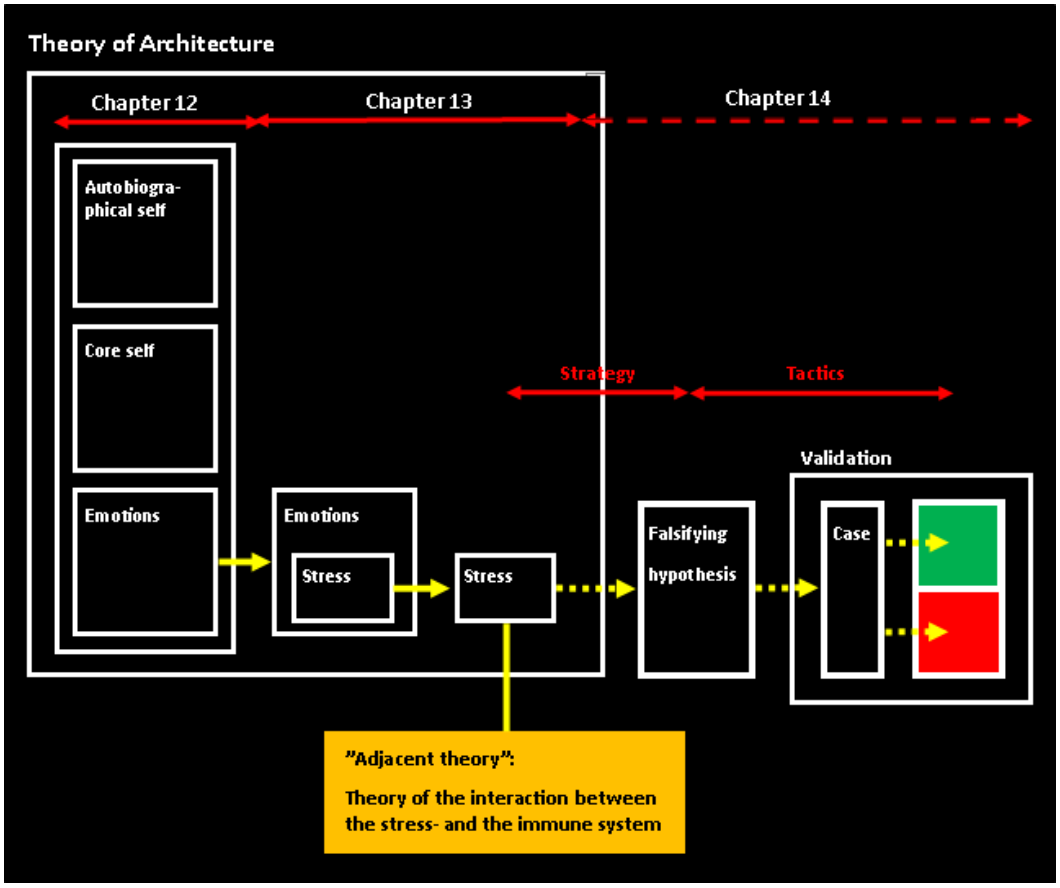

Fig 13.3. An outline of the theoretical development up until now and its progression on to empirical testing.

13.7.03 Formulating a theory of architecture, health, healing and well-being

In chapter 12, the interaction between subjects and their artificial environment in terms of architecture was discussed. The part of this transaction which will be covered by the theory is depicted in fig. 14.4.

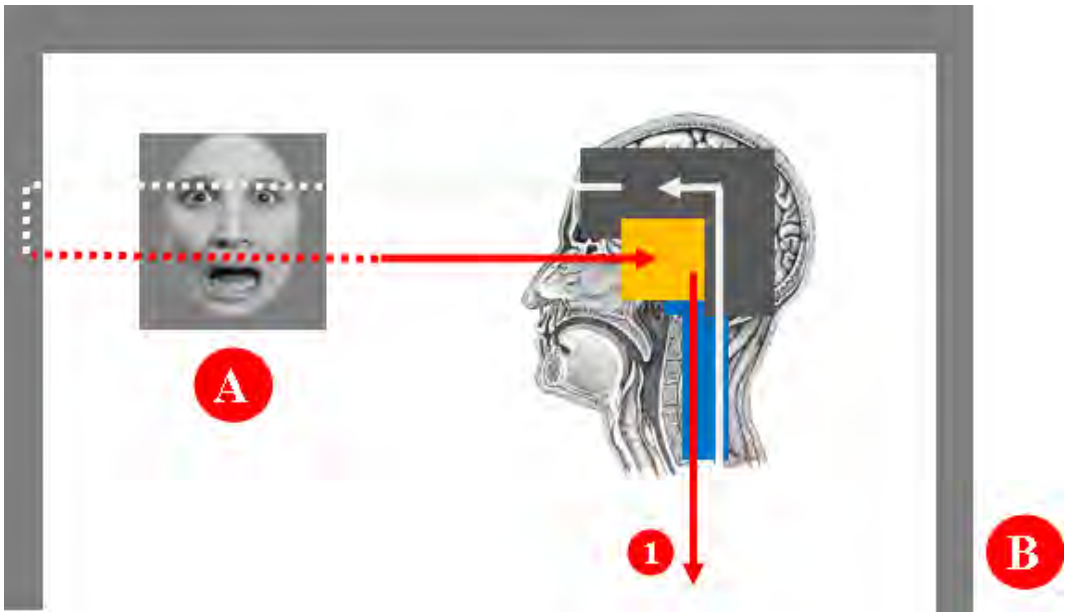

Fig. 14.4. The inquiry whether architecture can influence the physiological stress reaction only covers parts of the environment/body loop circle. The emotional system adjusts the body in accordance with the total complex of the stressful event A and the envelope B. Since a stressful event will always be an interruption of the normal, it is not to be expected that the design of the building envelope or space in itself can trigger a stress response. Rather the stress reaction will be a result of event + environment. The resulting endocrine or immune reaction 1 can then be measured.

On the basis of this, the following theory can be put forward: As stress is understood as a state of threatened homeostasis, and as the building envelope essentially is constructed to ease the maintenance of homeostasis, architecture can contribute to reduce the disadvantages for health, healing and well-being associated with stress through features of the building envelope that address homeostatic demands. By homeostatic demands is understood as those that correspond to systemic and psychogenic stress. Thus the magnitude of an activation of the stress effector systems in connection with an adaptive

reaction to a stressful event that takes place in a built environment will depend on the design of the building envelope and the space it forms. As it is assumed that the stress system influences the immune system, the design of the building envelope and the space it forms will be able to influence the operation of the immune system. Since a stressful event will always be an interruption of the normal, it is not to be expected that the design of the building envelope or space in itself can trigger a stress response. Rather the stress reaction will be a result of event + environment

Thus the class of potential falsifier will be 1) features of the building envelope, as only those which will affect the appraisal of the stress triggering sites will have an impact, 2) properties of the space formed by the building envelope for the same reasons and 3) types of stressors, as the stress-management system might be sensible to spatial features in different ways depending on e.g. if it is systemic stress such as pain, or psychogenic stress such as a demanding social situation. The criteria for falsification will be whether the stress effector systems dependent on the architectural properties of the envelope is activated all together, partly or not at all. If possible, directly measurable effects mediated by the immune system on e.g. wound healing might be used. All these classes of potential falsifiers have the potential to modify or reject the theory, and as such the potential to elicit scientific progress.

14

Empirical test of the falsifying hypothesis

In this chapter a falsifying hypothesis is developed, and the empirical test of it is presented. Only the conclusion concerning the test of the hypothesis itself is presented in this chapter, while the discussion in relation to the overall project is found in the following concluding chapter.

The experiment presented was conducted as collaboration between the

Department of Architecture, Design and media technology, Aalborg University, Denmark.
Department of Laboratory Medicine, Division of Occupational and Environmental Medicine, the Behavioral Medicine Research Group, Lund University, Sweden;
Department of Civil Engineering, Aalborg University, Denmark;
Department of Design Sciences, Lund University, Sweden;
The National Research Centre for the Working Environment, Denmark;
Department of Public Health, University of Copenhagen, Denmark;
Copenhagen Stress Research Center, Copenhagen, Denmark.

The experiment was funded by "Det Obelske Familiefond" and "Realdania" , both private non-profit foundations.

This chapter provides the validation of the theory, which is divided into two phases. The strategy constitutes the overall plan for the validation process, in this case the formulation of the best possible falsifying hypothesis, while the tactics constitute the detailed test of it (Groat and Wang, 2002, p. 10).

14.1.01 Strategy

The falsifying hypothesis must constitute a specific case of the theory's prediction: that the design of the building envelope can influence the magnitude of the physiological stress response to a stressful event. Furthermore, it must enable measurements that make it possible to conclude whether the prediction in this particular case has confirmed or disconfirmed the theory. To do so the following must be developed: 1) a testable hypothesis with the greatest possible chance of falsifying the theory; 2) an appropriate research design and 3) an appropriate method of measure must be applied. Stress is, as it has been apparent, closely linked to fight-or-flight behavior, as much of the bodily regulation that takes place is concerned with preparing the body for this type of behavior, by releasing stored energy resources and temporarily reducing energy-consuming processes that are irrelevant to the stressful challenge. The design of the building envelope should therefore address this stress-related behavior. If architecture fails to influence the physiological stress response by addressing the fight-or-flight behavior, it is improbable that other architectonic configurations that less directly target a behavioral stress response will succeed, and it will seem reasonable to regard the theory as falsified. If a design more peripheral to stress-related behavior is used and fails, it is still very possible that a design that directly targets the fight-or-flight response might succeed, and it will therefore not be possible to regard the theory as falsified on the ground of such an experiment, although the result was negative. It is therefore proposed to test how participants react to stress in a space which potentially offers a possibility for flight in terms of openings, versus a space with no openings that does not offer a potential possibility to escape the stressor.

14.1.02 Hypothesis

As the aim of the experiment then is to test whether the response of the stress systems to a stressful event depends on whether the space in which the stressful

event takes place constitutes openness versus enclosure, the following hypothesis is tested:

Participants faced with a standard stressor in a closed room will react with a more pronounced SNS and HPA reactivity than those in the a room with openings.

14.2 Tactics:

14.2.01 The standardized stressor

To produce a research design where stress could be induced in a controlled architectural context, a virtual reality version of the Trier Social Stress Test (VR-TSST) was used. The traditional Trier Social Stress Test (TSST) is perhaps the most widely used standard protocol for inducing psychosocial stress in laboratory settings (Kirschbaum et al. 1993; Kudielka & Hellhammer 2007). The participants have to perform a series of tasks in front of a committee that traditionally consists of trained actors. In the VR-TSST both the committee and the space in which the tests are performed are computer generated using a CAVE^{TM} system, and have been shown to induce stress reactions comparable to that of the traditional TSST (Jönsson et al. 2010). As the “building envelope” is computer generated, this allows for systematic variation of architectonic properties of the test-room.

14.2.02 The VR-TSST

The spatial context in which the VR-TSST is performed consists of a combined preparation/recovery room and a test-room where the committee is placed. The TSST is composed of three psychosocial stressors which have to be conducted in front of the committee in the test room, namely anticipatory stress in the form of an incomplete instruction by the committee about one of the tasks, a public speech task and a mental arithmetic task (Kirschbaum et al. 1993). Preparation of the speech and a recovery phase after the tasks take place in the preparation/recovery room. As spatial stimuli two versions of the test-room were developed, a

completely closed room and a room with three large openings through which the floor of the room stretched to the horizon, offering a potential possibility for flight (see fig. 14.1).

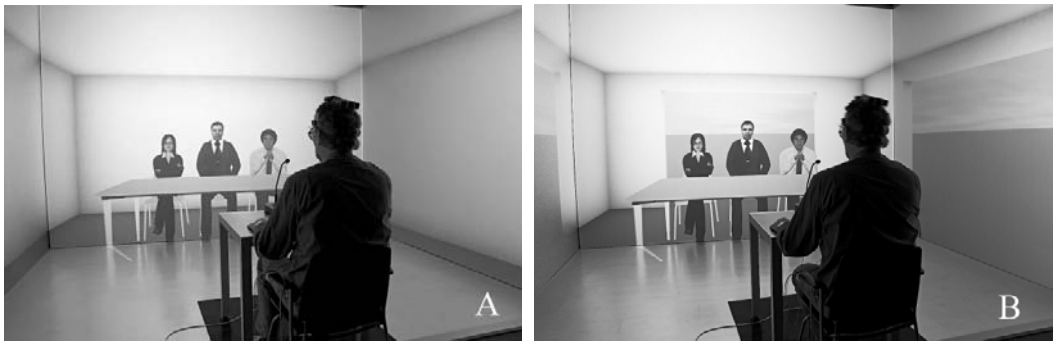

Fig. 14.1. A participant in front of the committee in the closed room (A) and the open room (B). Due to the stereoscopic projection, the participant will experience a clear 3D environment.

Franz et al. (2005) mention a possible bias in a virtual reality experiment due to objects seen through openings. To avoid this, the test room was designed in such a way that the space outside the open room was completely empty containing no objects or landscape characteristics whatsoever. The sky of the outside landscape was neutral grayish. However, a hint of clouds was added to make the 3D perspective adjustment effect work, so that the outside clearly moved in perspective when the participants moved their heads. It was thereby ensured that the openings could not be experienced as mere wall decoration. The computer generated experience of the space as well as of the committee is created by a system of projectors that project on to projection walls and the floor (Jönsson et al., 2010; Wallergård, et al., 2011). The 3D effect is obtained by passive stereoscopy and a head tracking system. The head tracking system allows real time perspective adjustments inside the virtual environment, which is important to

obtain a realistic sense of space (Snow and Williges, 1998). The design of the virtual test setting was kept as close to the study by Jönsson and colleagues (2010) as possible to avoid any bias due to change in the virtual environment or procedure and also the same CAVE™ and laboratory, computer modeled committee and waiting/recovery room as were used in prior studies were used (Jönsson et al., 2010; Wallergård et. al., 2011; Annerstedt et al., 2013).

The experiment protocol was as follows:

1. BASE: The participant entered the VR waiting/recovery room and a 5 min. baseline was recorded.
2. ANTICIPATION: The participant was then let into the other virtual room, the test room, facing the committee. The transition between the two rooms was made virtual, meaning that the participant did not leave the chair. He was told that after preparation, they were going to give a presentation in front of the committee, pretending that he was applying for a specific job. He was also told that, after the presentation, the committee would give him a second task to perform, but without specifying the task.
3. PREPARATION: The participant was transferred back to the waiting room to prepare the speech for 5 min. He was permitted to take notes during preparation, but was not allowed to use them during the presentation.
4. SPEECH: The participant once again entered the test room and gave his presentation in front of the committee (5 min.).
5. MENTAL ARITHMETIC: The participant performed the second task, which consisted of counting backwards from 1687 in steps of 13 as fast and accurately as possible. When errors occurred he was told by the chairman of the committee to start over again. (5 min.).
6. RECOVERY: The participant returned to the preparation/recovery room and rested for 40 min.

In the traditional TSST the actors respond to the participants with a set of standardized lines in situations predefined by the protocol and are instructed not to

show any emotional responses, whereas in the VR-TSST the committee members respond with a set of pre-recorded lines which are activated by the researcher.

14.2.03 Procedure

As suggested by Kudielka and Hellhammer (2007), the VR-TSST sessions were held in the afternoon because of the diurnal rhythm of cortisol, in which the curve is less steep in the afternoon. Two runs were performed each day, one starting at 1 p.m. and another at 3 p.m. Every second day, the first session was in the closed room followed by a session in the open room and vice versa. Upon arrival the participant was placed in a comfortable chair at a small table. The participant remained seated at the table during the whole session, and the movements between recovery-room and test-room were provided by pre-recorded paths in the virtual environment. The participant was then asked to fill in some papers covering background data and informed consent. The participant was informed that the experiment was going to last an hour and a half, and physiological recording equipment was attached and checked. Furthermore, the participant was told that the test session would be recorded for further analysis, and the table at which the participant sat was equipped with a fake video camera and microphone. The participants were not informed that the experiment had anything to do with the design of the test-room. To avoid that the purpose of the study was revealed, precautions were taken that no participants saw the other test room.

14.2.04 Participants

The participants were young healthy men, age between 19 and 31 (mean age 23.9). All were students from various departments at Lund University, Sweden. Students following the architectural program were excluded as it is known that their acquired expertise might alter their perception of architectural settings (Kirk et al. 2009). The participants were restricted to young males given the relative small number of participants, because of a known gender and age dependent

difference in HPA-axis responses, and because female cortisol response is known to be dependent of menstrual cycle and use of oral contraceptives (Kirschbaum et al. 1992; Kudielka & Hellhammer 2007; Kudielka et al. 2009).

The HPA-axis stress response to the TSST habituates quickly (Schommer et al. 2003). Jönsson and colleagues (2010) found that with the VR-TSST, this effect is very manifest already at the second exposure to the test. A strong bias could therefore be expected if the same participants were exposed to both settings, and consequently participants were randomly assigned to two groups of approximately the same size; one for the closed room and one for the open (25 in the open setting, 24 in the closed setting). Subsequently, 5 participants had to be excluded: 2 because of alcohol intake the day before, 2 because of medication (Otrivin nasal spray and Imurel, an immunosuppressive drug), and 1 because cortisol detection failed.

Only about 70 % of the population can be expected to generate a cortisol stress response that increases at least 2.5 nmol/l over baseline during TSST due to genetic factors as well as habituation effects (Kirschbaum et al., 1993; Pruessner et al., 1997; Kudielka et al., 2009). Therefore 12 (25 %) participants who failed to generate a HPA - stress response were excluded. This left 16 for the open setting and 14 for the closed one.

The participants were each given 2 cinema tickets for their participation. The study was approved by the central ethical review board at Lund (Dnr 2012/551) and was conducted in correspondence with the Helsinki declaration. All participants signed a form that clearly stated that participation was voluntary and could be discontinued at any time and they were verbally informed hereof, as well.

14.2.05 Measurements:

Activity of the HPA-axis was measured by its end product cortisol. This is possible to measure in saliva samples, in which it can be detected with an approximate 10 min. delay compared to free plasma cortisol (Hellhammer et al. 2009; Foley and Kirschbaum 2010). In contrast to collecting blood samples which would in itself have constituted a stressor, taking saliva samples is a non-invasive method. Saliva samples was collected every 10 min.

As a proxy of PNS and SNS activity, high frequency heart rate variability (HF-HRV) and T-wave amplitude (TW A) were estimated, respectively. The heart rate (HR) is under the control of the ANS' to divisions, the PNS and the SNS. Thus it is possible by analyzing the heart rate variability (HRV), which refers to the variations in the beat intervals, to measure the activity of the SNS and PNS separately, using an electrocardiogram (ECG) in which sympathetic activity is associated with low frequencies and parasympathetic activity is associated with the higher frequencies. Thus analysis of differences in frequencies allows the separation of the contributions of the SNS and ANS. Normally, corrections have to take place regarding different physiological factors influencing HRV, such as gender, age, respiration and body position, but in this case only respiration was relevant, thus respiration was also measured (Sztajzel, 2004; Acharya et al., 2006).

14.2.06 Data collection and reduction

All saliva samples were stored at -20°C until analyzed. At the day of analysis, the samples were left to thaw at room temperature for approximately 45 min and centrifuged at 3500 g for 10 min. Liquid-liquid extraction of 200 µl saliva with 1 ml ethyl acetate, evaporated to dryness under nitrogen flow and re-dissolved in 200 µL 10 % methanol (MeOH) was carried out as described by Jensen et al (2011). D-4-cortisol was used as internal standard. The calibration range was 0.5 – 90.0 nmol/L.

14.2.07 Cortisol

A volume of 25 µL was injected into an Agilent 1200 HPLC (Agilent technologies, Santa Clara, CA, USA) equipped with a C18 2.1x50 mm 2.6 µm Kinetex column and a Krud-katcher ultra filter (Phenomenex, Torrance, CA). The mobile phase consisted of a 2 mM aquatic solution of ammonium acetate with 0.1 % (v/v) formic acid (A) and MeOH with 2 mM ammonium acetate and 0.1% (v/v) formic acid (B). A linear gradient was run over 3 min from 10 % to 100 % B and maintained at 100% MeOH for 1,5 min, followed by 2 min of equilibration at 10% MeOH resulting in a total run time of 6.5 min. The flow rate was 0.5 mL/min and the temperature of the auto sampler and column oven was 8°C and 40°C, respectively. Detection of cortisol was performed by a mass spectrometer, an Agilent 6460 QQQ (Agilent technologies, Santa Clara, CA) equipped with a jet stream ESI ion source, was operated in the positive ion mode as described by Jensen et al (Jensen et al. 2011). The flow and temperature of the dry and sheath gases were: 11 L/min, 350ºC, 8 L/min and 400ºC, respectively. The nebulizer gas pressure was 50 psi and the capillary voltage was 4,5 kV. The quantification was achieved by using low-energy collision induced tandem mass spectrometry (CDI-MS/MS) in the multiple reaction monitoring (MRM) mode. A single precursor ion – product ion transition was measured for each hormone and its internal standard. The transitions were: m/z 363.2→m/z 121.1 for cortisol; m/z 367.2→m/z 121.2 for D-4-cortisol.

To show equivalence between different runs, natural saliva samples (2.5 nmol/l and 11.9 nmol/l) were used as control materials and analyzed together with the samples. Westgard control charts were used to document that the analytical method remained under analytical and statistical control − in other words, that the truth and the precision of the analytical methods remained stable (Westergard et al., 1981). The performance of the methods has been further validated by participation in interlaboratory comparison schemes (Garde et al., 2003; Hansen et al., 2003)

14.2.08 Heart rate

ECG and respiration were recorded at 1 kHz using the ML866 Power Lab data acquisition system and analyzed using its software Chart5 (ADInstruments Pty, Bella Vista, Australia) and MATLAB (Mental Arithmetic Works, Natick, MA). ECG was assessed using disposable electrodes (Lead II Einthoven) and respiration using a strain gauge over the chest. Mean HR was analyzed for 5 min. in each condition: BASELINE, PREP, SPEECH, MENTAL ARITHMETIC, and during the four following recovery periods, for a total of 8 conditions. The same was done in the case of T-wave amplitude (TWA) and HRV, see below.

14.2.09 T-wave amplitude (TWA)

TWA is suggested to be related to β-adrenergic sympathetic influences on myocardial performance (Rau, 1991). Although its reliability has been questioned by some researchers (Furedy & Heslegrave, 1983) it has been found to respond in conformity with other β-adrenergic indicators such as pre-ejection period (PEP) and R-to pulse interval (RPI) to stressful tasks (Montoya et al.,1997). TWA was computed as the difference in mV between the maximum 100 – 300 milliseconds (ms) after the R-wave peak and the mean of the isoelectric period (40 ms) between the P- and Q-wave (Rau, 1991) for each heartbeat and averaged over 5 min.

14.2.10 High frequency heart rate variability (HF-HRV)

ECG and respiration were sampled at 1 kHz. R-R intervals were transformed to a tachogram (ms) and linearly interpolated at 4 Hz. The data was further linearly detrended and high-pass filtered (second order Butterworth filter, 0.10 Hz) to eliminate fluctuations below the respiratory frequency. For each 5-min sequence, HRV power spectra were calculated, for 17 segments of 128 points (32 s) with 50% overlap, by means of fast Fourier transform (1024 points) following the application of multiple peak matched windows. The Peak Matched Multiple

Windows (PM MW) method optimizes the mean square error of the spectrum estimate when the spectrum can be expected to include peaks (Hansson, 1999; Hansson and Salomonsson, 1997). The PM MW method has been shown to give reliable results for the HRV spectrum (Hansson-Sandsten and Jönsson, 2007; Hansson and Jönsson, 2006) and has previously been used in psycho-physiological research (Annerstedt et al.; Jönsson, 2007; Jönsson & Hansson-Sandsten, 2008; Jönsson et al., 2010). The integral of the power spectrum was studied in the high frequency (HF) region (0.12 – 0.4 Hz) that is related to respiration (Berntson et al., 1997). The data was log-transformed (ln) to approach a normal distribution. The respiration measures were used to ensure that the respiratory rate was within the HF range.

14.2.11 Statistics

Repeated measures ANOVA were used in all analyses for the physiological measures ($p < 0.05$), with experimental CONDITION as within-subject repeated factor and GROUP as the between-subject factor. Significant effects were reported with Huynh-Feldt adjustments (ε) to correct for violation of the assumption of sphericity, together with unadjusted degrees of freedom and adjusted *p*-values. The statistics were based on Δ-scores with baseline values as subtrahends.

14.2.12 Results

Cortisol

The repeated measures ANOVA showed a significant main effect of CONDITION: F(5, 140) = 35.84, p < . 0001, = .56, ε = .41. Saliva cortisol increased during TSST and peaked about 10 min. after stress induction after which it decreased over the 3 last recovery conditions, as indicated by a quadratic trend [F(1, 28) = 89.06, p < .0001, = .76]. A cubic trend [F(1, 28) = 37.87, p < .0001, = .58] shows that the cortisol increase was steeper than the decrease.

Also a GROUP*CONDITION interaction was found showing that cortisol reactivity was more pronounced in the group that was in the closed room: F(5, 140) = 3.10, p = .05, = .10, ε = .41; linear trend (F(1, 28) = 6.37, p = .02, = .19.

The main effect of GROUP was close to significant only: F(1, 28) = 3.91, p = .06, = .12.

Heart rate

Also HR increased during TSST and then returned during recovery: F(6, 162) = 71.73, p < .0001, = .73, ε = .47, confirmed by linear [F(1, 27) = 124.17, p < .0001, = .82], quadratic [F(1, 27) = 13.83, p = .001, = .34], and cubic trends [F(1, 27) = 53.40, p < .0001, = .66].

No other significant results were found.

T-wave amplitude

In concert with HR, sympathetic activity increased (TWA decreased) during TSST and then returned during recovery: F(6, 162) = 26.68, p < .0001, = .50, ε = .40, with linear [F(1, 27) = 32.03, p < .0001, = .54] and cubic trends [F(1, 27) = 29.37, p < .0001, = .52].

No other significant results were found.

HF-HRV

After an initial decrease from baseline, HF-HRV magnitude increased over the following conditions and stabilized during recovery: F(6, 162) = 9.35, p < .0001, .26, ε = .41, linear [F(1, 27) = 13.40, p = .001, = .33] and quadratic trends [F(1, 27) = 23.65, p < .0001, = .47].

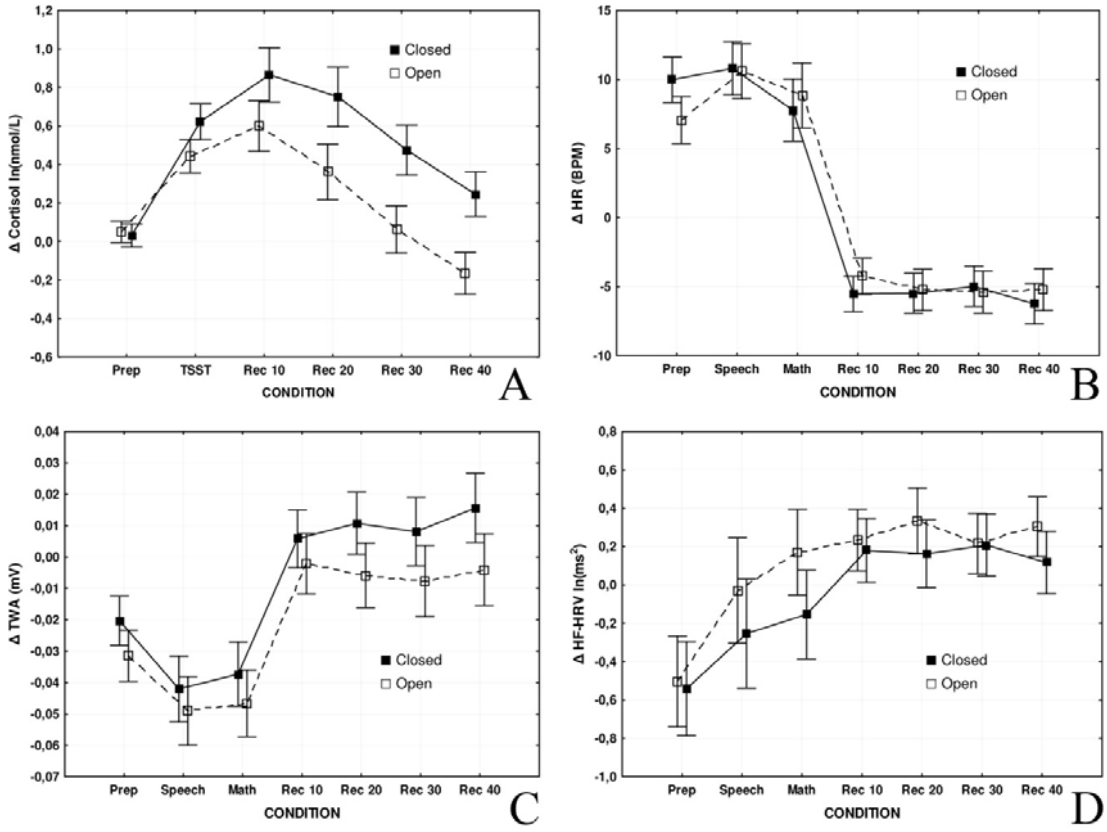

Fig. 14.2

A: Cortisol (A), B: heart rate (HR , C: T-wave amplitude (TWA) and D: high frequency heart rate variability (HF-HRV) as function of the experimental condition. Activity of the HPA-axis was measured by its end product cortisol in saliva samples, in which it can be detected with an approximate 10 min. delay compared to free plasma cortisol, meaning that e.g. values specified under "TSST" is actually a measure for the level of plasma cortisol under "prep". As a proxy of PNS and SNS activity we estimated high frequency heart rate variability (HF-HRV) and T-wave amplitude (TWA), respectively.

14.2.13 Conclusion

The ANS and HPA-axis measures indicated that the stress induction was successful. Saliva cortisol and HR increased, and TWA decreased (increased SNS activity) during the VR-TSST. PNS mediated HF-HRV magnitude decreased during the preparation condition of VR-TSST and slowly increased during the speech and the mental arithmetic task, and then stabilized at still higher magnitudes during recovery.

Neither part of the ANS differentiated as a function of whether the envelope was closed or had openings, but the HPA-axis differentiated as predicted with a more pronounced reactivity in the closed room than in the open one (see fig. 14.2). The difference in cortisol secretion grows steadily from stress on-set at the anticipatory stage during the speech and mental arithmetic task until 10 min. into the recovery phase (read under Rec. 20 on fig. 14.2 due to the 10 min. delay), after which the difference is stable, suggesting that the HPA-axis is sensitive to the spatial context indiscriminately of type of stressor (anticipatory, public speech or mental arithmetic)). As the two stress systems react differently, the hypothesis is therefore confirmed for the HPA-axis, but disconfirmed for the ANS.

It can therefore be concluded that whether an envelope to a space in which a stressful event takes place is closed or has openings influences the reaction of HPA-axis, and that a high degree of openness seems to give a less pronounced secretion of cortisol, as predicted.

14.2.14 Discussion.

As only the HPA-axis was sensitive to whether the envelope was equipped with openings or not, the structures guiding the HPA-axis stress reaction but not the ANS might therefore be the key to a more profound understanding of whether or not other spatial features might be expected to influence the HPA-axis. Research is beginning to reveal that there is a considerable division of labor between the

structures that govern the stress effector systems of the SNS and the HPA-axis, respectively. The fact that the SNS didn't react to the openness of the envelope while the HPA-axis does therefore makes it possible to discuss which structures might be responsible. As the hippocampus is only involved in the control of the HPA-axis the possible involvement of the hippocampus in the spatial assessment seems likely, because only the HPA-axis seems to be sensitive to whether there were openings in the envelope or not (Herman and Mueller, 2006; Herman et al., 2005; Herman et al., 2003; Jankord and Herman, 2008; Dedovic et al., 2009; Ulrich-Lai and Herman, 2009; Andrews et al., 2013). This is interesting, as the hippocampus as mentioned is involved in boundary learning and processing of environmental geometry (Doeller and Burgess, 2007; Doeller et al., 2008). The involvement of such structures as the hippocampus suggests that other known spatial parameters that require an advanced processing of the spatial boundary e.g. ceiling height (Meyers-Levy and Zhu, 2007) or curvilinear versus rectilinear spaces (Vatarian et al., 2013), might also be capable of influencing stress.

15

Conclusion

In this chapter, the content of the thesis will be summarized and conclusion will be drawn concerning the scientific contribution in relation to the scientific objectives of the thesis. Moreover, further directions of research are discussed based on questions raised about the results.

15.1 Summary

The personal motivation for writing this Ph.D., is grounded in personal experience. I have worked as an architect for 25 years, partially with hospital design. In connection with a hospital project in which I was the project manager, I was involved in the research project “Healing Architecture” (Helende Arkitektur) within the Department of Architecture, Design and Media Technology at Aalborg University – in fact the “Healing Architecture” project was born out of the hospital project.

Thus the thesis was born out of a personal wonder, perhaps enhanced by working with health architecture regarding how far architecture's ability to affect people actually reaches, and a resulting fascination of pursuing this wonder with curiosity through research. This fascination came about through participation in the “Healing Architecture” project – but also, I must admit, by a feeling of dissatisfaction and “unfinished business” concerning the “Healing Architecture” project. The basic question, despite its title, left unanswered by the “Healing Architecture” project, was what became the initiating research questions of this thesis:

- *Can the perception of architecture affect health?*

Which is a subset of an even broader question:

- *Can the perception of architecture affect us physiologically?*

To understand the role of architectural research by understanding what it has had to offer to the architectural practice throughout history, a historical overview was conducted. This identified the effort to create theories that can help predicting the effect of yet unbuilt buildings, as going back at least to the Roman architect and theorist Vitruvious from the 1st century BC. Thus architectural research is by no means a new phenomenon, and has been carried out throughout history with the means characteristic of each age, demonstrating that it is an integrated part of the architectural practice. A turning point in the development of such theories in a modern sense was identified as the theory of the French theorist Marc-Antoine Laugier (1713-1769).Towards the end of the Enlightenment, he put forward a theory on architecture, which for the first time made man, or to be more specific, the physiological needs of the human body, the yard stick of architecture, replacing the religiously based concept of architecture that had dominated the previous centuries. In this way, the research in architecture was turned into research in humans. Today it is taken as a matter of course to conduct research in architecture by studying the impact of architecture on humans in terms of questionnaires, observation of people etc. Thus research in architecture is per this definition multidisciplinary, defined as it is by all the different scientific sources of knowledge of humans. At hand for the architectural researcher are all sciences that study humans, and choices between methodologies and scientific approaches can be made according to the research task at hand. Furthermore, Laugier's theory basically divides architectonic elements into two groups; structural elements, which is the prerequisite, and the building envelope, which is the means to mediate between the interior and the surrounding environment.

Through chapter 8 a methodological approach was developed, mainly based on the abductive reasoning of Charles Sanders Peirce (1839-1914) and the fallibilism of Karl Popper (1902-1994) which, it is claimed, have very much in common. The model developed is built on the conception that the effort of epistemology is to separate the creation of theories from the validation of them, as the creation of theory inevitably (and hopefully) will contain elements of imagination and intuition that do not in themselves lend validity to the theory. Thus, to underline the creative character of this stage, a part of it is named with a term applied to it by Popper: “Mythmaking” (Popper 1973, p. 83). Separated from this is a validation process in which the theory is tested by attempts to falsify the theory, by deriving falsifiable hypotheses from the theory that can be

empirically or otherwise tested. A theory is then, following Popper, to be regarded as a temporary conjecture only, and knowledge becomes a process rather than an absolute (Popper 1953, 1974, p. 102).

15.1.01 Creation of the theory; “Myth making”.

Following the methodological scheme laid out, a state-of-the-art literature review was conducted, partly based on “Healing Architecture”, which has the character of a comprehensive state-of-the art report. The selected literature was evaluated according to criteria derived from the initial research question, that research relevant to answering these questions must concern architecture, understood as the built environment (e.g. not nature), must include perception, and must initiate a physiological response related to health. Based on these criteria, it was concluded that actually none of the reviewed research papers fulfill all criteria. It is concluded that this is due to 1) tendency to make the architecture a constant (e.g. *identical* patient bedrooms with different views), with the consequence that very little information about the architecture itself can be derived, 2) a tendency to measure e.g. the *amount* of light or sound, which cannot fulfill the demands of the definition of perception applied, according to which perception involves an “interpretation of sensory information in order to represent and understand the environment” (Schacter, 2011) and 3) either a lack of understanding of physiological mechanisms tying a physical variable to a health outcome, or a lack of proper understanding of how physiological mechanisms interact with the architectonic environment. To make a contribution to the existing knowledge base, the objectives for the research conducted in this thesis are therefore subsequently that 1) architecture is regarded as a variable 2) the theory is built upon some of the physiological mechanisms through which its effect is brought about and 3) the attempt to tie perception of architecture, an understanding of the underlying physiological mechanisms, and the expected physiological effect on health, together. Furthermore, three mechanisms through which the physical environment might influence health were derived from the literature, proposed by different writers, namely stress, the placebo effect and distraction.

The next question that had to be discussed was whether healing and perception are at all comparable phenomena that can be investigated through the same methods. In order to examine the relationship between perception on the one hand and physiological reactions

on the other, a brief discussion of the classical mind-body problem is conducted in chapter 10 “An assumption regarding the relationship between mind and body”. As a reasonable assumption it was concluded that: “Mental phenomena are caused by neurophysiological and other biological processes within an organism in interaction with its environment, and are themselves features of the organism according to its inherent mental capacity”. This assumption defines both the processes related to perception and those governing health as biological processes. The inquiry from this point onwards was therefore about finding connections between two equal and comparable processes, namely those physiological processes that constitute health and those that constitute perception, respectively. In chapter 11 “A Definition of Health, Healing and Well-being” it was, using Wiley’s definition that : “Health is the perfect, continuing adjustment of an organism to its environment” (Wiley, 1970) established, that the key concept for understanding this continuous adaption is the homeostatic balance – the idea that an organism must keep its internal milieu constant despite the fluctuations of the surrounding environment to stay alive - and that compromised health or well-being fundamentally can be understood as compromised homeostasis. From this point on, the inquiry was therefore further delimited to processes that relate perception and homeostasis. Furthermore, as disease can be understood as a state of homeostatic imbalance and well-being as a state of perfect balance, it is difficult to completely separated the two, as they are at either end of a continuous scale. In chapter 12 “Architecture and the Biology of Consciousness” the connection between homeostasis and perception was searched for, mainly using the theories of Antonio Damasio, as his theory with homeostasis – the prerequisite for staying alive - as its basis, strives to explain all levels of interaction between the organisms and its environment from the most basic life regulatory mechanisms to consciousness. The result was the identification of three levels with importance for the understanding of how perception of the environment governs the relationship between an organism and its environment, namely emotions, core self and the autobiographical self. As the task of emotions according to Damasio *is* homeostatic regulation, while the core and autobiographical selves are rather related indirectly to it, the further search was delimited to emotional processes. Furthermore, Laugier's division of architectural elements into two groups, namely structural elements as a prerequisite and the building envelope as a mediator between the interior and the surrounding environment, was confronted with the idea of homeostasis. The building

envelope can now be seen as a device to promote homeostasis. It is evident that separating the organisms from the fluctuations and threats of the environment by the construction of a building envelope largely eases the task of keeping the homeostatic balance. Emotional mechanisms as well as others that by evolution are created to react in a meaningful way to natural environments, are now confronted with the artificial environment delimited by the building envelope, constructed by the very same agents that have to react to it, namely humans. By this, architecture becomes a collective part of the emotion – core self – autobiographical self-circle.

On the basis of the properties that characterize the emotional systems, the stress systems is chosen for further investigation, though the other two mechanisms pointed to as well in chapter 9 “State of the art” is also briefly discussed. There is no scientific consensus about the definition of stress, and a recommended practice is therefore to apply a definition of stress in each separate case (Manson, 1975b, p.34). As the homeostatic balance is a central concept in this thesis, the definition of Chrousos, Loriaux and Gold is used: “The term “Stress” describes a state of threatened “homeostasis” (Chrousos, Loriaux and Gold, 1988, cited in Johnson et al. 1992).

Through chapter 13 “Stress”, the stress systems and their relation to perception and homeostasis are discussed. An important relation of the stress systems to homeostasis is their relation to the immune system, and the different reactions of the immune system to different durations of stress are discussed. The relationship between the stress systems is well established. This link is presented as an “adjacent theory” meaning that it will be considered outside the range of this thesis to test it.

It has been established, that the building envelope mediates homeostasis. Further, it has been established, that stress can be understood as “a state of threatened homeostasis”. The theory can then be put forward, that “architecture can contribute to reduce the disadvantages for health, healing and well-being associated with stress, through features of the building envelope that addresses homeostatic demands”, as it through the adjacent theory is assumed, that the stress systems influence the immune system. Thus it is assumed, that the design of the building envelope and the space it forms might hereby be able to influence the operation of the immune system.

The perception that governs the stress systems is largely non-conscious and in contrast to conscious perception, which is characterized by categorization of recognized objects. Research indicates that non-conscious perception to a larger degree perceives the environment as an entity, thus the appraisal of a stressful event will be inseparable from the environment e.g. the building envelope or the space created by it, and the adaptive stress reaction will therefore be modulated by it.

15.1.02 Validation of the theory

To test the theory, a falsifying hypothesis must be developed. This must have the form of a special empirical testable case meaning, according to Popper, that it must divide the class of all possible outcomes of the experiment into two not-empty sub-classes; those which 'confirm' the theory and those which falsify it. To do so, clearly defined measurements must be defined that make it possible to decide whether or not the results predicted by the theory are produced. It should be noted that the theory is not proved, if it is not falsified; a theory can never be proved, just made more trustworthy. In contrast, it is disproved if it is falsified.

The experiment must be designed in such a way, that the architecture in the form of the envelope is the independent variable, and the physiological measure is the dependent variable, to avoid the situation found in the state-of-the-art review, in which very little information about the architecture itself actually was obtained by the experiments, because the architecture was a constant. Further, the design of the envelope must "address homeostatic demands". The most classic adaptive behavior associated with stress is the fight-or-flight behavior. By choosing this, the biggest chance for falsification is obtained; if the theory can't predict a reaction tied to the fight-or-flight behavior, it is unlikely that it will be able to predict a reaction based on a more peripheral adaptive stress reaction. Conversely, if an envelope design that refers to a more peripheral reaction is chosen and fails, it would still be likely that a design related to the fight-or-flight reaction will work. Thus the research design must consists of a stressful event that takes place in a space that is either closed offering no potential possibility for flight, or a space with openings, which potentially allows for flight.

This is obtained by using a virtual version of the Trier Social Stress Test (VR-TSST). The traditional Trier Social Stress Test (TSST) is perhaps the most used standard protocol for laboratory experiments with psychosocial stress. A participant has to perform a series of psychosocial stressful tasks in front of a committee, consisting of three trained actors. In the VR-TSST the space in which the test is performed as well as the committee are computer generated, using a CAVE™ system. A set of projectors controlled by a computer creates an illusion of a three dimensional reality, by projecting of a series of screens and the floor. Because the space is computer generated, the architecture of the envelope can be systematically manipulated. Thus a computer model of a closed space, and a space with three large openings through which the floor stretches uninterrupted to the horizon, is generated. The 'landscape' outside the open space is empty, not containing any objects that in themselves could seem attractive or repulsive.

It could be objected that a simplified architectural model like this cannot account for the complexity found in 'real' architecture. Indeed, in chapter 9, "State of the art", Kim Dirckinck-Holmfeldt, co-author of "The hospital of the senses", was cited for writing, that it is "not possible to conduct studies based on evidence of the experience of subjective space, unless one is satisfied with the analyses of primitive and stereotyped spatial types" (Hesleth and Dirckinck-Holmfeldt, 2007, p. 256). He is undoubtedly right, if an understanding of architecture should be brought about inductively through analyses of an endless number of empirical observations. However, this is not the case in this study. Conversely, the experiment is an attempt to falsify, to disprove, a theoretical statement about architecture. Thus, the model is not chosen to prove anything about architecture, but to as effectively as possible to potentially *disprove* the hypotheses, that has been derived from the theory.

In the experiment, a number of measures of the physiological stress reaction is made. As proxies of stress are measured cortisol and the activity of the sympathetic nervous system. The stress hormone cortisol can be measured in saliva samples, and is secreted under the control of the HPA-axis, which is the one of the stress effector systems. The activity of the autonomous nervous systems to divisions, the sympathetic and parasympathetic nervous system can be calculated from measures of heart rate variability.

The hypothesis tested was:

Participants faced with a standard stressor in a closed room will react with a more pronounced sympathetic nervous system (SNS) and Hypothalamo-Pituitary-Adrenocortical (HPA) axis reactivity than those in an open room.

The result of the experiment was that the HPA-axis did react with a lower level of cortisol secretion for participants in the open space than in the closed space, but no difference was found for the SNS between participants in the two spaces. Thus the hypothesis was confirmed for the HPA-axis and disconfirmed for the SNS.

The fact that only the HPA-axis reacted, and that the autonomic nervous system (ANS), of which the SNS is a part, did not, allows for a discussion of which brain structures might be involved in the process. The HPA-axis and the ANS are governed through different though to some degree overlapping systems. Attention might be directed towards the hippocampus, which is involved in spatial navigation, and which is part of a feedback mechanism that regulates the HPA-axis, but not the ANS.

15.2 Conclusion

The experiment showed that the degree of openings in a building- or space envelope offering a potential possibility for escape will alter the HPA-axis reaction to acute stress.

Therefore I conclude, that architecture influences physiology, and presumably thereby health, healing and well-being.

The proposed theory is therefore strengthened, and is due to the falsification concerning architecture's lack of effect concerning the SNS, clarified to:

As stress is understood as a state of threatened homeostasis, and as the building envelope essentially is constructed to ease the maintenance of homeostasis, architecture can contribute to reducing the disadvantages for health, healing and well-being associated with stress reactions mediated by the HPA-axis, through features of the building envelope that address homeostatic demands.

Thus theory seems to fulfill the criteria for the demanded scientific contribution that resulted from the discussion following the literature review in the state-of-the art chapter:

1. The theory has architecture as its variable.
2. The theory demonstrates a physiological outcome related to the architectonic environment.
3. The theory provides an understanding of which physiological mechanisms presumably are involved.

Furthermore, a research method for future research along these lines has been developed.

The experiment is however associated with a number of limitations which at the present stage will make it rather pretentious to talk about “Healing Architecture” on the basis of the results described in this thesis.

The experiment only covers healthy young men, and it only includes the part of the population that is known to belong to the 70% reacting to a TSST with HPA-axis activation, whether it is traditional or virtual.

This is a laboratory experiment, in which everything possible has been done to ensure that the effect of only one variable is measured. The upside of this is the possibility to isolate the variation of architecture as the independent variable, producing a relative high degree of internal validity. The downside is that, as it notoriously will be in laboratory experiments, that the effect size compared to other environmental factors and their possible interplay is not known, thus the external validity is relatively low. Such knowledge will probably in the end only be attainable through field-studies.

The experiment due to its protocol only accounts for acute stress that, as has been discussed, even has some positive effects on the immune system, while the effect on the immune system turns to negative when the stress is brought about by brief naturalistic stressors or chronic stress. As it for ethical reasons probably is impossible to conduct human laboratory experiments with brief naturalistic, chronic stressors or repeated acute stressors that reach the same effect, knowledge of the possible effect on architecture on

these types of stressors must be obtained in field-studies. This will demand that a substantial knowledge about e.g. the architectonic environment needed is acquired beforehand, through further laboratory experiments.

Furthermore, as far as the question whether architecture can influence health, healing and well-being is concerned, the study rests on the well-known connection between the stress system and the immune system. Though it is very well established, it is also very complex, as it has been discussed. If possible, direct measures of the reactions of the immune system must be preferable - and preferable for different durations of stress, which further calls for field-studies.

In the context of hospital patients, there is an issue concerning base-line, which needs to be addressed. Due to its protocol, the VR-TSST experiment has only revealed the reactions in healthy people to acute stress on the basis of a non-stress baseline. However, patients in a hospital would in many instances be in a state where the immune system, HPA-axis and ANS to some degree might be activated in an abnormal way. As far as the HPA-axis is concerned, activation might both be due to stress or its interaction with the immune system. The base-line of hospital patients might therefore be expected to be much more diverse and incomparable to healthy people. In order to determine whether for example the effects attainable by manipulation of the built environment under these circumstances would be too small to have any effect, or conversely that the dampening of even minor acute stressors to prevent acute stress to add on to a general state of stress in vulnerable patients, knowledge of the state of the immune and stress system of hospital patients distributed on age, gender, treatment and stage of treatment is needed. It is possible that the necessary data already exists, as hospital patients are very closely monitored.

15.3 Future research

As this is the first study of its kind, it naturally has a preliminary character. As a consequence, a lot of questions are raised calling for further research.

15.3.01 Prolonged duration of stress

The VR-TSST or the TSST by its protocol only deals with acute stress. As has been apparent from the brief discussion on the immune system, the effect is very different depending on the duration of a stress episode, ranging from the beneficial to the handicapping. Therefore there is an obvious need for investigating prolonged stress episodes, which for ethical reasons probably must be conducted as field studies.

The VR-TSST consists of three acute stressors, each with durations of 5 min. The result seems to confirm that several acute stress incidents in succession add up to an overall stronger stress response. Furthermore, for subjects undergoing acute stress of comparable magnitude to the VR-TSST in closed or open rooms, the ones in the open rooms would start at a lower baseline than those in the closed room, if an acute stressor is launched within approx. 30. min. Further laboratory studies along these lines could help shed a light on this, as it will be very relevant in understanding how every-day stress that often will consists of a series of acute stressors, is influenced by architecture.

15.3.02 Different stressors

The current experiment is carried out with psychosocial stressors. However, the reaction to a physical stressor such as pain might be somewhat similar. A possibility would be the so called cold-pressor test, which is a standard protocol for experiments with physical stressors in the form of pain. The participant places a hand in approx. $5C^{o}$ cold water, which will be experienced as pain. Measurements of saliva cortisol and heart rate variability like those in the TSST can then be made. The experiment could be carried out in the exact same computer model, to obtain comparability.

15.3.03 Other measures

In the context of architecture's influence on health, it would be preferable to directly measure the effect on the immune system, as has been mentioned above. As the effect of the HPA-axis is quite slow compared to the ANS, this will call for a methodological development if it should be carried out in a VR-TSST like set up. If a field- study research design should be obtained, inspiration might be found in the research on music therapy.

15.3.04 The landscape

Ulrich (1984) found, that the view to nature shortened hospitals stays and reduced the use of drugs, compared to a view to another hospital building. It will be possible to manipulated the character of the landscape outside the open room systematically, to compare the effect size of the two effects and investigate whether an interplay takes place e.g. if the character of the environment to which a potential flight is possible has any effect.

15.3.05 Relevance to other fields than hospital design

In chapter 11 “A Definition of Health, Healing and Well-being”, it was concluded that: “health, well-being and disease cannot be discussed separately, but should rather be seen as a scale with a smooth transition from perfect biological adaptation and well-being in the one extreme, to total biochemical maladaptation and imbalance in the other extreme”. As a consequence it was further concluded that: “it is not possible to make an inquiry into “healing architecture” as an isolated topic; it is not possible to make a clear distinction between architecture that is healing, and architecture that is not or is indifferent to health. Rather the study must try to uncover whether perception of the environment can influence the homeostatic balance and if so, how the properties of the built environment systematically can do so”. As a result, the inquiry therefore cannot be seen as an isolated statement on the possibility of “Healing Architecture”. Rather its results include how the perception of architecture may influence the whole range from perfect homeostatic balance to critical imbalance. The result is therefore relevant for other instances that include stress than those of hospitals. Especially the field of working environment must be considered in this regard e.g. is it possible that the design of the boundary or space envelope influences the level of stress at the workplace, and thereby the health and well-being of those who work there as well as their performance.

15.3.06 Other architectonic configurations

This research project has succeeded in identifying a characteristic of the envelope of a building or space that can provide a measurable HPA-axis response to psychosocial stress. This is based on the fundamental fight-or-flight behavior, and thereby related to the

maintenance of the homeostatic balance by non-conscious structures in the brain. The question is whether rooms that offer a possibility for flight by being more or less open is the only parameter that through these mechanisms can affect us physiologically. Research done in a research group on architecture and neuroaesthetics, of which the author of this thesis is a member, has in a fMRI experiment identified contour (Vartanian et al., 2013a) and ceiling height as possible candidates (Vartanian et al. 2013b).

From a more general, architectural point of view, it seems with the background in the results of the experiment that Böhme's statement "Perception is basically the manner in which one is bodily present for something or someone or one's bodily state in an environment." (Böhme, 1993) is to be taken rather literally. As the palette of architectonic atmospheres is much more nuanced than being stressed/not-stressed, it seems that there is a very large area to explore regarding the body's reactions to different environmental configurations, including the conscious experience of these reactions. As the nuanced conception of atmospheres is developed within philosophy, this might call for an interesting cross-disciplinary research effort, involving the humanities as well as the more naturalistic sciences.

15.4 Communication

In chapter 6 “Research in Architecture” the role of architectural research, and the communication to what was defined as the normative and artistic level was discussed. Furthermore, it was pointed out in chapter 8 “Epistemological approach”, that the challenge of this communication often is, that while knowledge is a process of continuously replacing theories and models with new ones with improved predictive power, the popular concept of scientific knowledge is often quite different. In popular conception, scientific knowledge is often perceived as absolute truth and, as it was stated: “ A difference in perception will create mistrust and undermine the cooperation between the different levels, at the expense of the benefits society can derive from research”. Obviously, this is certainly true for a theory that is on a very preliminary stage such as this one, and precautions must therefore be taken not to communicate in a way that pretend that a greater confidence may be had in the theory, than the preliminary stage can justify. The theory is first and foremost intended for the artistic level, the architects, as they are primarily responsible for the effect of their designs, and thereby for predicting with some certainty that what is promised in their proposals will have the expected effect. As many within the architectural profession are not by training familiar with the scientific process, great precautions must be taken to emphasize that this is an emerging field rather than an established theory. It must be considered if the least secure parts of the theory should be communicated at all to the artistic level, at this stage. As the same concerns regarding the understanding of the scientific process will be relevant to many within the normative level, the same considerations regarding communication might be taken in this instance. In both instances, the risk of over- or mis-communication will be, that the theoretical understanding of how the perception of architecture can affect our bodies and health is misinterpreted by the normative and artistic level, as being absolute truth and not a preliminary results. As the result at the present level of the theory is far from being able to deliver precise prediction for a number of reasons discussed above, failure to deliver such predictions might result in a general distrust in research result. However, among the normative level it might be beneficial to communicate more intensely with members of the medical profession, as they certainly have the scientific training, the expertise and the knowledge about the actual issues, which might be addressed through architecture. In this respect, something might perhaps be learned from

music therapy that has proved successful in Denmark, for example in connection with the suppression of pre-surgery stress and stress in the first crucial time in ambulances. On the other hand, the preliminary stage of the theory underlines the need for further research of a multidisciplinary kind as has been discussed above. To ensure a qualified development of the theory through discussion and collaboration particularly for a multidisciplinary approach like this, the need for communicating with various disciplines within the scientific community is crucial.

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17
Appendix

As it has been discussed in section 15.4 "communication", it is, especially for a multidisciplinary approach like this, crucial to communicate with various relevant disciplines within the scientific community, to ensure a qualified development of the theory through discussion and collaboration. In this appendix to journal papers, which has been submitted on the basis of this thesis, in order to communicate its theoretical viewpoints and empirical results, is reprinted.

17.1 "Architectural design can alter the physiological reaction to psychosocial stress; a virtual TSST experiment."

Authors: Lars Brorson Fich, Peter Jönsson, Poul Henning Kirkegaard, Mattias Wallergård, Anne Helene Garde, Åse Hansen,

Journal: Physiology and behavior

17.2 "Architecture and the biology of consciousness"

Authors: Lars Brorson Fich, Åse Hansen, Poul Henning Kirkegaard,.

Journal: Architectural Research Quarterly submitted.

17.1

Fich L.B., Jönsson P., Kirkegaard P.H., Wallergård M., Garde A.H., Hansen, Å., 2013. Architectural design can alter the physiological reaction to psychosocial stress; a virtual TSST experiment. *Physiology and behavior*, submitted.

This paper, submitted to "Physiology and behavior", presents the results, and is to a large extend based on chapter 14 in the thesis.

Architectural design can alter the physiological reaction to psychosocial stress; a virtual TSST experiment.

Abstract.

As the fight-or-flight behavior has since the days of Walter B. Cannon been recognized as a stress coping strategy, we therefore hypothesized, that the potential possibility for flight might modulate the stress response. If so, spatial properties of an architectural design of a space in terms of openness versus enclosure, potentially allowing for escape or no escape, might influence the physiological stress response to a stressful event, taking place within the space. Using a virtual version of the Trier Social Stress Test, in which the space is computer generated and properties of the space therefore could be systematically varied, we measured saliva cortisol and heart rate variability in participants in a closed room versus an a room with openings. The result showed that participants in the closed room responded with more pronounced cortisol reactivity compared to participants in the open room, but no differences were found regarding any part of the autonomic nervous system.

Key words: Stress, Cortisol, Architecture, Openness, Enclosure, Spaciousness, TSST, VR-TSST, Virtual reality Trier Social Stress Test, Trier Social Stress Test; .

1.0 Introduction

Since the days of Walter B. Cannon, the fight-or-flight behavior has been considered a basic adaptive behavior to stress (Cannon, 1914). The modern conception still is, that the purpose of the activation of the stress effector systems, the sympatho-adrenomedullary (SAM) system and the hypothalamic-pituitary-adrenal (HPA) axis, is to prepare the organism to such behavior. This is done through the release of stored energy resources, increase of blood pressure, heart rate and respiration, and the suppression of energy consuming processes that is not temporarily needed such as feeding and digestion, sexual behavior and the specific immune system (McEwen, 2008; Denson et al. 2009). The appraisal of whether a threatening situation that demands the preparation of a flight-or-fight behavior is thought to be carried out by a complex interplay between a number of limbic structures within the brain, including the amygdala (AMG), hippocampus (HC) and the prefrontal cortex (PFC) (Herman et al. 2005; Dedovic et al. 2009; Ulric-Lai and Herman, 2009), while the actual coping strategy chosen is mediated by the periaqueducal gray (PAG), which can launch different coping strategies depending on among other factors, such as whether the stressor is escapable or inescapable (Keay and Bandler, 2001). Thus it seems reasonable to hypothesize, that the stress response will be modulated depending on whether escape is possible and, that spatial features in the environment therefor might influence the magnitude of a stress reaction. Thus it might be reasonable to assume, that the stress response to a stressfull ebent that takes place in a building, might be influenced by certain properties of its architecture. In this study, we induced stress in two different settings; a) in a closed room potentially not allowing escape, and b) in a room with three large openings potentially allowing for escape.

We used a virtual reality version of the Trier Social Stress Test (VR-TSST), (Jönsson, et al., 2010). The traditional Trier social stress test (TSST) is perhaps the most widely used standard protocol for inducing psychosocial stress in laboratory settings (Kirschbaum et al. 1993; Kudielka & Hellhammer 2007). The participants have to perform a series of stressful tasks in front of a committee that traditionally consists of trained actors. In the VR-TSST both the committee and the space in which the tests was performed was

computer generated using a CAVE™ system, and has been shown to induce stress reactions comparable to that of the traditional TSST (Jönsson et al., 2010).

Because the aim of the study was to test whether the stress systems' response to a stressful event depends on the openness versus enclosure of the architectural space in which a stressful event takes place, the hypothesis was tested that participants performing the VR-TSST in the closed room would respond with more pronounced SNS and HPA reactivity than participants that was tested in the open room. As proxies of PNS, and SNS activity high frequency heart rate variability (HF-HRV) and T-wave amplitude (TWA) were calculated respectively (Berntson et al., 1997; Kline, Ginsburg, & Johnston, 1998; Rau, 1991). Activity of the HPA-axis was measured by its end product cortisol in saliva samples, in which it can be detected with an approximately 10 min. delay compared to free plasma cortisol (Hellhammer et al. 2009; Foley and Kirschbaum 2010).

2.0 Methods

2.1 The VR-TSST

The spatial context in which the VR-TSST was performed consisted of a combined preparation/recovery room and a test-room where the committee was placed. The TSST was composed of three psychosocial stressors which have to be conducted in front of the committee in the test-room, namely anticipatory stress in the form of an incomplete instruction by the committee about one of the tasks, a public speech task and a mental arithmetic task (Kirschbaum et al. 1993). Preparation of the speech and a recovery phase after the tasks takes place in the preparation/recovery room. The one test room was without openings all together, while the open room which should offer a potential for escape, had three large openings, through which the floor of the room stretched to the horizon (see Fig. 1).

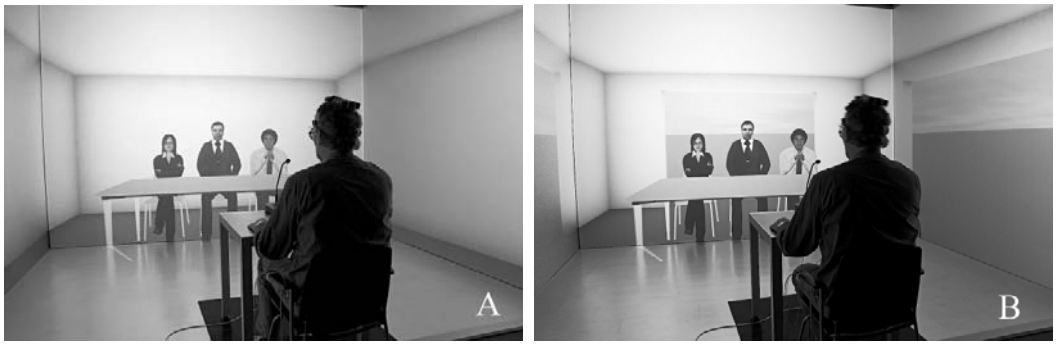

Fig. 1. A participant in front of the committee in the closed room (A) and the open room (B). Due to the stereoscopic projection, the participant will experience a clear 3D environment.

Franz et al. (2005) mention a possible bias in a virtual reality experiment due to objects seen through openings. To avoid this, the test-room was designed in such a way that the space outside the open room was completely empty containing no objects or landscape characteristics whatsoever. The sky of the outside landscape was neutral gray. However, a hint of clouds was added to make the 3D perspective adjustment effect work, and thereby ensure that the openings could not be experienced as mere wall decoration. The computer- generated experience of the space, as well as the committee, were created by a system of projectors that project on to the walls and the floor (Jönsson et al., 2010; Wallergård, et al., 2011). The 3D effect is obtained by passive stereoscopy and a head tracking system. The head tracking system allows real time perspective adjustments inside the virtual environment, which is important to obtain a realistic sense of space (Snow and Williges, 1998). The design of the virtual test setting was kept as close to the study by Jönsson and colleagues (2010) as possible to avoid any bias due to change in the virtual environment or procedure; the same CAVE^{TM} and laboratory, computer modeled committee and preparation/recovery room was used as in prior studies (Jönsson et al., 2010; Wallergård et. al., 2011; Annerstedt et al., 2013).

2.2 Procedure

As suggested by Kudielka and Hellhammer (2007), the VR-TSST sessions were held in the afternoon ; one starting at one p.m. and another at three p.m. Every second day the first session was in the closed room followed by a session in the open room and vice versa. Upon arrival the participant was placed in a comfortable chair at a small table. The participant remained seated at the table during the whole session, and the movements between recovery-room and test-room were provided by pre-recorded paths in the virtual environment. The participant was then asked to fill in some papers covering background data and informed consent. The participant was informed that the experiment was going to last an hour and a half, and physiological recording equipment was attached and checked. Furthermore, the participant was told that the test session would be recorded for further analysis; the table at which the participant sat was equipped with a fake video camera and microphone. The participants did not know that the experiment had anything to do with the design of the test-room. To avoid revealing the purpose of the study, precautions were taken that no participants saw the other test-room.

The experiment protocol was as follows:

1. BASE: The participant entered the VR preparation/recovery room and a 5 min. baseline was recorded.

2. ANTICIPATION: The participant was then let into the other virtual room, the test-room, facing the committee. He was told that after preparation, they were going to give a presentation in front of the committee, as if applying for a specific job. The participant was also told that, after the presentation, the committee would give a second task to perform, but without specifying the task.

3. PREPARATION: The participant was transferred back to the preparation/recovery room to prepare the speech for 5 min. He was permitted to take notes during preparation, but was not allowed to use them during the presentation.

4. SPEECH: The participant once again entered the test-room and gave a presentation in front of the committee (5 min.).

5. MATH: The participant performed the second task, which consisted of counting backwards from 1687 in steps of 13 as fast and accurately as possible. When errors occurred he was told by the chairman of the committee to start over again. (5 min.).

6. RECOVERY: The participant returned to the preparation/recovery room and rested for 40 min.

In the traditional TSST the actors respond to the participants with a set of standardized lines in situations predefined by the protocol and are instructed not to show any emotional responses. In the VR-TSST, the committee members respond with a set of pre-recorded lines which are activated by the researcher.

2.3 Participants

The participants were young healthy men, age between 19 and 31 (mean age 23.9). All were students from various departments at Lund University, Sweden. Students following the architectural program were excluded as it is known that their acquired expertise might alter their perception of architectural settings (Kirk et al. 2009). The participants were restricted to young males given the relative small number of participants, because of a known gender and age dependent difference in HPA-axis responses, and because female cortisol response is known to be dependent of menstrual cycle and use of oral contraceptives (Kirschbaum et al. 1992; Kudielka & Hellhammer 2007; Kudielka et al. 2009).

The HPA-axis stress response to the TSST habituates quickly (Schommer et al. 2003). Jönsson and colleagues (2010) found that with the VR-TSST, this effect is already manifests by the second exposure to the test. A strong bias could therefore be expected if the same participants were exposed to both settings; consequently participants were randomly assigned to two groups of approximately the same size; one for the closed and one for the open room (25 in the open setting, 24 in the closed setting). Subsequently five participants had to be excluded: two because of alcohol intake the day before, two because of medication (Otrivin nasal sparay and Imurel, an immunosuppressive drug), and one because cortisol detection failed.

Only about 70 % of the population can be expected to generate a cortisol stress response that increases at least 2.5 nmol/l over baseline during TSST due to genetic factors as well as habituation effects (Kirschbaum et al., 1993; Pruessner et al., 1997; Kudielka et al., 2009). Consequently 12 (25 %) participants who failed to generate a HPA - stress response, were excluded. This left 16 for the open setting and 14 for the closed.

The participants were each given 2 cinema tickets for their participation. The study was approved by the central ethical review board at Lund (Dnr 2012/551) and was conducted in accordance with the Helsinki declaration. All participants signed a form that clearly stated that participation was voluntary and could be discontinued at any time; they were also verbally informed hereof.

3. Data collection and reduction

All saliva samples were stored at -20°C until analyzed. At the day of analysis, the samples were left to thaw at room temperature for approximately 45 min and centrifuged at 3500 g for 10 min. Liquid-liquid extraction of 200 µl saliva with 1 ml ethyl acetate, evaporated to dryness under nitrogen flow and re-dissolved in 200 µL 10 % methanol (MeOH) was carried out as described by Jensen et al (2011). D-4-cortisol was used ad internal standard. The calibration range was 0.5 – 90.0 nmol/L.

3.1 Cortisol

A volume of 25 µL was injected into an Agilent 1200 HPLC (Agilent technologies, Santa Clara, CA, USA) equipped with a C18 2.1x50 mm 2.6 µm Kinetex column and a Krud-katcher ultra filter (Phenomenex, Torrance, CA). The mobile phase consisted of a 2 mM aquatic solution of ammonium acetate with 0.1 % (v/v) formic acid (A) and MeOH with 2 mM ammonium acetate and 0.1% (v/v) formic acid (B). A linear gradient was run over 3 min from 10 % to 100 % B and maintained at 100% MeOH for 1.5 min, followed by 2 min of equilibration at 10% MeOH resulting in a total run time of 6.5 min. The flow rate was 0.5 mL/min and the temperature of the auto sampler and column oven was 8°C and 40°C, respectively. Detection of cortisol was performed by a mass spectrometer, an Agilent 6460 QQQ (Agilent technologies, Santa Clara, CA) equipped with a jet stream ESI ion source, and was operated in the positive ion mode as described by Jensen et al

(Jensen et al. 2011). The flow and temperature of the dry and sheath gases were: 11 L/min, 350ºC, 8 L/min and 400ºC, respectively. The nebulizer gas pressure was 50 psi and the capillary voltage was 4,5 kV. The quantification was achieved by using low-energy collision induced tandem mass spectrometry (CDI-MS/MS) in the multiple reaction monitoring (MRM) mode. A single precursor ion–product ion transition was measured for each hormone and its internal standard. The transitions were: m/z 363.2→m/z 121.1 for cortisol; m/z 367.2→m/z 121.2 for D-4-cortisol.

To show equivalence between different runs, natural saliva samples (2.5 nmol/l and 11.9 nmol/l) were used as control materials and analyzed together with the samples. Westgard control charts were used to document that the analytical method remained under analytical and statistical control − in other words, that the trueness and the precision of the analytical methods remained stable (Westergard et al., 1981). The performance of the methods has been further validated by participation in inter-laboratory comparison schemes (Garde et al., 2003; Hansen et al., 2003)

3.2 Heart rate

ECG and respiration were recorded at 1 kHz using the ML866 Power Lab data acquisition system and analyzed using its software Chart5 (ADInstruments Pty, Bella Vista, Australia) and MATLAB (MathWorks Inc., Natick, MA). ECG was assessed using disposable electrodes (Lead II Einthoven) and respiration using a strain gauge over the chest. Mean HR was analyzed for 5 min in each condition: BASELINE, PREP, SPEECH, MATH, and during the four following recovery periods, for a total of 8 conditions. The same was done in the case of T-wave amplitude (TWA) and HRV, see below.

3.3 T-wave amplitude (TWA)

TWA is suggested to be related to β-adrenergic sympathetic influences on myocardial performance (Rau, 1991). Although its reliability has been questioned by some researchers (Furedy & Heslegrave, 1983), it has been found to respond in conformity with other β-adrenergic indicators such as pre-ejection period (PEP) and R-to pulse interval (RPI) to stressful tasks (Montoya, Brody, Beck, Veit, & Rau, 1997). TWA was computed as the difference in mV between the maximum 100 – 300 milliseconds (ms) after the R-

wave peak and the mean of the isoelectric period (40 ms) between the P- and Q-wave (Rau, 1991) for each heartbeat and averaged over 5 min.

3.4 High frequency heart rate variability (HF-HRV)

ECG and respiration were sampled at 1 kHz. R-R intervals were transformed to a tachogram (ms) and linearly interpolated at 4 Hz. The data was further linearly detrended and high-pass filtered (second order Butterworth filter, 0.10 Hz) to eliminate fluctuations below the respiratory frequency. For each 5-min sequence, HRV power spectra were calculated, for 17 segments of 128 points (32 s) with 50% overlap, by means of fast Fourier transform (1024 points) following the application of multiple peak matched windows. The Peak Matched Multiple Windows (PM MW) method optimizes the mean square error of the spectrum estimate when the spectrum can be expected to include peaks (Hansson, 1999; Hansson & Salomonsson, 1997). The PM MW method has been shown to give reliable results for the HRV spectrum (Hansson-Sandsten & Jönsson, 2007; M. Hansson & Jönsson, 2006) and has previously been used in psychophysiological research (Annerstedt et al.2013 ; Jönsson, 2007; Jönsson & Hansson-Sandsten, 2008; Jönsson et al., 2010). The integral of the power spectrum was studied in the high frequency (HF) region (0.12 – 0.4 Hz) that is related to respiration (Berntson, et al., 1997). The data was log-transformed (ln) to approach a normal distribution. The respiration measures were used to ensure that the respiratory rate was within the HF range.

3.5 Statistics

Repeated measures ANOVA were used in all analyses for the physiological measures ($p < 0.05$), with experimental CONDITION as within-subject repeated factor and GROUP as the between-subject factor. Significant effects were reported with Huynh-Feldt adjustments (ε) to correct for violation of the assumption of sphericity, together with unadjusted degrees of freedom, adjusted *p*-values, and η^2_{part} . The statistics were based on Δ-scores with baseline values as subtrahends.

4. Results

Cortisol

The repeated measures ANOVA showed a significant main effect of CONDITION: $F(5, 140) = 35.84$, $p < .0001$, $\eta^2_{part} = .56$, $\varepsilon = .41$. Saliva cortisol increased during TSST and peaked about 10 min after stress induction after which it decreased over the three last recovery conditions, as indicated by a quadratic trend [$F(1, 28) = 89.06$, $p < .0001$, $\eta^2_{part} = .76$]. A cubic trend [$F(1, 28) = 37.87$, $p < .0001$, $\eta^2_{part} = .58$] shows that the cortisol increase was steeper than the decrease.

Also a GROUP*CONDITION interaction was found showing that cortisol reactivity was more pronounced in the group that was in the closed room: $F(5, 140) = 3.10$, $p = .05$, $\eta^2_{part} = .10$, $\varepsilon = .41$; linear trend ($F(1, 28) = 6.37$, $p = .02$, $\eta^2_{part} = .19$.

The main effect of GROUP was close to significant only: $F(1, 28) = 3.91$, $p = .06$, $\eta^2_{part} = .12$.

Heart rate

Also HR increased during TSST and then returned during recovery: $F(6, 162) = 71.73$, $p < .0001$, $\eta^2_{part} = .73$, $\varepsilon = .47$, confirmed by linear [$F(1, 27) = 124.17$, $p < .0001$, $\eta^2_{part} = .82$], quadratic [$F(1, 27) = 13.83$, p = .001, $\eta^2_{part} = .34$], and cubic trends [$F(1, 27) = 53.40$, $p < .0001$, $\eta^2_{part} = .66$].

No other significant results were found.

T-wave amplitude

In concert with HR, sympathetic activity increased (TWA decreased) during TSST and the returned during recovery: $F(6, 162) = 26.68$, $p < .0001$, $\eta^2_{part} = .50$, $\varepsilon = .40$, with linear [$F(1, 27) = 32.03$, $p < .0001$, $\eta^2_{part} = .54$] and cubic trends [$F(1, 27) = 29.37$, $p < .0001$, $\eta^2_{part} = .52$].

No other significant results were found.

HF-HRV

After an initial decrease from baseline, HF-HRV magnitude increased over the following conditions and stabilized during recovery: $F(6, 162) = 9.35$, $p < .0001$, η^2_{part} .26, ε = .41, linear [$F(1, 27) = 13.40$, $p = .001$, $\eta^2_{part} = .33$] and quadratic trends [$F(1, 27) = 23.65$, $p < .0001$, $\eta^2_{part} = .47$].

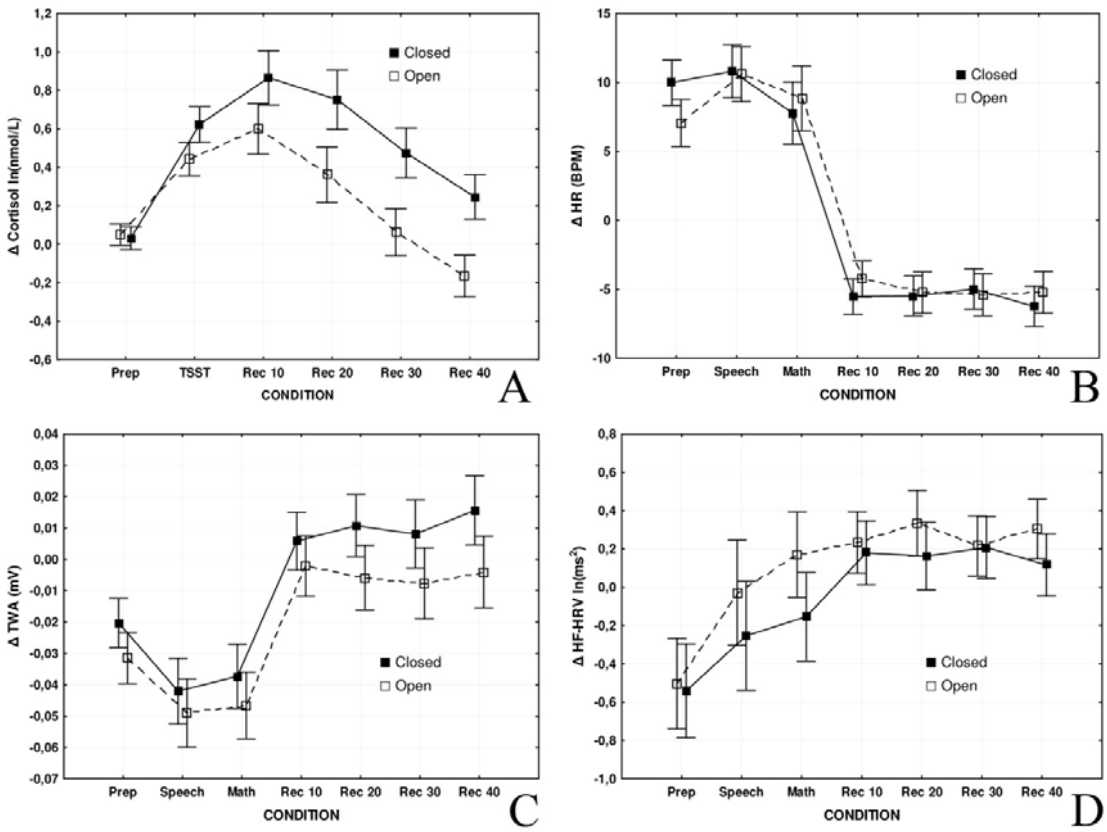

Fig. 14.2

A: Cortisol (A), B: heart rate (HR , C: T-wave amplitude (TWA) and D: high frequency heart rate variability (HF-HRV) as function of the experimental condition. Activity of the HPA-axis was measured by its end product cortisol in saliva samples, in which it can be detected with an approximate 10 min. delay

compared to free plasma cortisol, meaning that e.g. values specified under "TSST" is actually a measure for the level of plasma cortisol under "prep". As a proxy of PNS and SNS activity we estimated high frequency heart rate variability (HF-HRV) and T-wave amplitude (TWA), respectively.

5. Discussion

The ANS and HPA-axis measures indicated that the stress induction was successful. Saliva cortisol and HR increased, and TWA decreased (increased SNS activity) during the VR-TSST. PNS mediated HF-HRV magnitude decreased during the preparation condition of VR-TSST and slowly increased during the speech and the math task, and then stabilized at still higher magnitudes during recovery.

Neither part of the ANS differentiated as a function of openness versus enclosure, but the HPA-axis differentiated as predicted with a more pronounced reactivity in the closed room than in the open (see fig. 2). The difference in cortisol secretion grows steadily from stress onset at the anticipatory stage during the speech and math task until 10 min. into the recovery phase (read under Rec. 20 on fig. 2 due to the 10 min. delay), after which the difference is stable, suggesting that the HPA-axis is sensitive to the spatial context indiscriminately of type of stressor (anticipatory, public speech or math). As the two stress systems react differently, the hypotheses, it is therefore confirmed for the HPA-axis but disconfirmed for the ANS. It can therefore be concluded that the openness versus enclosure of a space in which a stressful event takes place influences the reaction of HPA-axis, and that a high degree of openness seems to give a less pronounced secretion of cortisol, as predicted.

The fact that the HPA-axis and the SAM-system reacted differently, might imply which mechanisms in terms of brain structures that was involved in the spatial appraisal process. The appraisal of stressors that represents a possible future threat rather than a direct disturbance of homeostasis such as psychosocial stress, is carried out through a complex interaction of structures primarily in the limbic system. The systems that govern the ANS and the HPA-axis are, though largely overlapping, not identical. Among the structures involved in the feed-back deactivation of the HPA-axis is the hippocampus (HC) (Ulrich-

Lai and Herman, 2009), which among other functions is involved in spatial navigation. As a part of this, the HC is involved in encoding characteristics of space boundaries (Doeller and Burgess, 2007; Doeller et al. 2008).

5.1 Limitations

There are a number of limitations associated with the results. The result includes only healthy young men, making the result unrepresentative for the population regarding gender, age and health. Furthermore, the VR-TSST only induces acute stress, and the effect on any kind of prolonged stress from brief naturalistic stress to chronic stress is not known. Stress is generally accepted to be a major health problem, especially related to the work place and health care facilities. The general recognition that the stress system has an influences on the immune system (Segestrom and Miller, 2006), had led to experiments with stress reducing interventions e.g. music therapy within the health care system. However, the general limitations within the group of participants and especially the fact that this experiment only dealt with healthy participants are major limitations to its relevance in relation to the health care sector. In addition, because it was a laboratory experiment only, the effect size cannot be compared to other effects. As far as the health care system is concerned, a further limitation is that the effect on the immune system is rather different, depending on the duration of the stress episode (Segestrom and Miller, 2006).

5.2 Future research

As stress is in general recognized as a major problem e.g. regarding health or concerning the working environment, it is obviously interesting if stress can be dampened through architectural design. However, as the limitations pointed out above suggests, further research is needed before it can be determined whether this is a realistic option. The VR-TSST only induces acute stress, and whether architectonic spatial qualities can influence prolonged or chronic stress cannot be revealed through this methodological approach. This is an important issue calling for a methodological development that might reveal whether spatial effects are capable of influencing prolonged stress as well, as dysregulation of hormone activity following prolonged stress might contribute to major life illnesses such as cancer, metabolic, cardiovascular, autoimmune and psychiatric

disorders (Sapolsky et al. 2000, McEwen 2008). Furthermore, only two spatial conditions have been tested. Many other spatial parameters concerned with safety such as horizontal area or contours, has proved to have psychological effects (Stamps, 2005; Stamps, 2009; Vatarian et al., 2013). Whether they will have physiological effects as well, or whether the effect of such parameters will accrue in combination or occasionally suspend each other, must all be questions for future research.

6.0 Akcnoledgements, funding and declaration of conflicting interests

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17.2

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ARCHITECTURE AND THE BIOLOGY OF CONSCIOUSNESS

In the past three decades or so, the fast progress of neuroscience has held a promise of providing new insights for almost all branches of research dealing with human beings in one way or another. This has certainly also been the case for research in the arts, where the emergence of the neuroaesthetic movement, advanced by Semir Zeki, has attracted a widespread interest within various artistic disciplines. Zeki deliberately limits his inquiry by restricting himself from the emotional content of art and "its ability to disturb and arouse and surprise"[1] and rather concentrates on finding the "Neural Correlates of Beauty" [2] which he envisions exist independently of emotions. Whether an isolated search for the neural correlate of "beauty" is relevant to architecture might of course be a matter of how one understands architecture. However, following a leading theorist within the discipline itself such as Juhani Pallasmaa, something deeper is clearly at stake as fare as architecture is concerned, as "Profound architecture does not merely beautify the settings of dwellings; great buildings articulate the experience of our very existence" [3]. In Pallasmaa's understanding: "Architecture, as with all art, is fundamentally confronted with questions of human existence in space and time, it expresses and relates man's being in the world. Architecture is deeply engaged in the metaphysical questions of the self and the world, interiority and exteriority, time and duration, life and death" [4]. If neuroscience should be able to fulfill its promise of contributing to a deeper understanding of

architecture on these premises, the search must clearly take place in other parts of its knowledge base than those of neurasthenics. However, recent discoveries in neuroscience itself begin to indicate that neurasthenics indeed were too narrow in scope, and that the phenomenon of the aesthetic appreciation of art cannot be seen in isolation. Brown and colleagues [5] concluded from a meta-analysis of 93 neuroimaging studies of positive aesthetic valance, that art is treated as any other object by the brain when it comes to aesthetic valance.. Conversely to Zeki's rejection of emotions in the context of aesthetics, they conclude that "Aesthetic processing, at its core, can thus be equated with *object-appraisal* processes, resulting in emotions that sit along the spectrum from transcendence to repulsion". Most interestingly they found that the single common denominator among brain centers implicated in valence processing for all the studies reviewed, was a center called the insula. The insula represents the interesting combination of possessing the highest degree of body-representation in the brain and being involved in the generation of subjective feeling states as well as the generation of the "material me" or "sentiment self" [6]. This suggests that the experience of subjective aesthetic valance is closely related to the body and generation of the self and consciousness, just as implied by Pallasmaa. The most comprehensive neurobiological theory of the integration of bodily presence, the self, consciousness and the environment is found in the comprehensive authorship of the American neurobiologist Antonio Damasio. The purpose of this essay will then be to investigate how neurobiological research along these lines as represented by the theory of Damasio can contribute to our understanding of architecture as a phenomenon. The first part will be a summary of Damasio's theory of consciousness, concentrating on the issues implied by Pallasmaa, omitting the neurological details as much as possible. The second part will be a discussion of the possible implications for- and contribution to our concept of architecture.

The non-conscious

A basic concept of the theory of Damasio, and a basic concept of modern physiology as such, is the concept of the homeostatic balance, coined by the American physiologist Walter B. Canon (1871-1945) in 1929[7]. Any living organism from the single celled bacteria to very complex multi-celled organisms like humans is faced with the challenge that the biochemical balance within each of the organism's cells has to be kept within

narrow biochemical limits, despite the fluctuations of the outer environment, which in comparison can be extreme. To ensure that the homeostatic balance can be kept Damasio notes that it is necessary for *any* organism to be able to find sources of energy, incorporating and transform energy, maintain the chemical balance of the interior compatible with the life processes, maintain the organism's structure by repairing its wear and tear and to fend off external agents of disease and physical injury [8]. An organism that cannot do this (or cannot reproduce) simply cannot exist.

By this, Damasio notes, biological value and intentionality have been introduced [9]. Although primitive single celled organisms do not possess the means to perceive it, there are "good" things and actions that sustain homoeostasis and thereby survival, and there are "bad" things that threaten homoeostasis, which can lead to extinction. As organisms have become more complex, homeostatic regulation has become equally more advanced. Values have been implemented as drives and instincts and administrated by reward and punishment devices [10].

It is of course dangerous for an organism to wait making homoeostatic adjustments until an actual imbalance has occurred. To protect against such situations, structures in the brain stem and so called limbic system rapidly and non-consciously are able to launch "complex, largely automated programs of *actions* concocted by evolution" [11]. Such non-conscious action programs are in neurobiology termed "emotions" which are not to be mixed up with conscious feelings. The task of such emotional programs is to ensure that the organism takes appropriate actions to protect its integrity, before homoeostasis has been disturbed. The sophistication and efficiency by which they carry out their task makes Damasio term emotions as the "crown jewel of life regulation" [12].While the downside of emotion programs might be considered to be that they are stereotypical, the upside seen from the point of view of survival is that they work very fast. This was already established in 1980 by the American psychologist Zajonc, who was able to conclude that " we can like something or be afraid of it before we know precisely what it is and perhaps even without knowing what it is" [13]. In summary the activation of an emotional program will cover 1) a coordinated and all-encompassing bodily regulation 2) release of a neurotransmitter, chemical compounds that are used to transmit signals between nervous cells, the neurons, in the brain. By altering the communication between

neurons in specific networks, the brain's mode of function is altered. 3) Involuntary behaviour and social signals e.g. flushing.

The Body Loop

In contrast, conscious feeling results from a perception of the regulation that takes place in the body and the altered state of mind that comes with the emotional program. In other words, a feeling is an entirely internal affair consisting of a perception of the altered state of the body including the brain. The emotion-feeling sequence forms a *body-loop* in which the emotional systems make adjustments to the body and brain, which are subsequently mapped by other structures in the brain responsible for the creation of feeling states. Thus, there is a marked contrast between the outward, direct emotional action programs designed to interact with the environment and the inward directed emotions, which are basically a sensory perception of the body itself [14]. Then, the emotion-feeling cycle can be described as such: 1) the organism interacts with an object in the external environment of homeostatic importance to the organism 2) to avoid disturbance of the homeostatic balance and prepare the organism for the encounter with the object this makes structures outside consciousness in the limbic system and brain stem launch an emotional program that includes adjustments to the body, the brain itself and to external behaviour 3) other parts of the brain map the body including the brain itself, resulting in conscious feeling.

Consciousness

The advantage of adding consciousness to the automated and relatively inflexible emotional systems is obvious. In the words of the neurobiologist Joseph LeDoux: “While many animals get through life mostly on emotional automatic pilot, those animals that can readily switch from automatic pilot to wilful control have a tremendous extra advantage. This advantage depends on the wedding of emotional and cognitive functions.” [15]. However, while the different levels of direct life regulation comprises very well researched and understood territories, the understanding of the biology of consciousness is still at a hypothetical stage, subject to controversy. However, a lot is known about which structures in the brain are involved in consciousness and which are not, from a variety of sources like brain injuries, pathological conditions like various

types of epileptic seizures, the effect of specifically targeted anaesthetic compounds and of course the various modern scanning techniques. Furthermore, a lot can be deducted from which neurotransmitters that are exclusively present in the awake brain, as only some circuits depend on these neurotransmitters [16]. From these sources it is also known that consciousness is far from monolithic. It can be partly lost, disturbed or regained, and even awake, normal functional individuals will experience different stages of being more or less intensely conscious. According to Damasio,a working definition of consciousness could be something like this: 1) consciousness is a state of mind in which the organism is awake and a self-process is added to the mind 2) consciousness is a state of mind in which there is knowledge of one's own existence and of the existence of surroundings 3) conscious mind states are always about something and 4) conscious states of mind contain an obligate aspect of feeling [17].

When cells began to form multi cellular organisms, two important steps in the evolution of the nervous system are of special relevance in this context. The first was the emergence of neurons which are basically body cells with an ability to influence other cells including other neurons. By this they achieve the capability to transmit signals and build complex networks, and ultimately form centralized, coordinating organs of life regulation in terms of a brains. Primitive brains and nervous systems contain only so called dispositional networks, forming organisms that are relatively simple "response machines". When such an organism interacts with an object, signals from its sense organs might through its nervous system activate its motor systems and make it move; there is no record of where the organisms were in the first place or any representations of the object [18]. The second important step was the development of an additional type of brain tissue, which is composed of layers of neurons ordered in a precise grid pattern. This allows the brain to create *maps* in the form of patterns of activated neurons, that sometimes rather literally and sometimes rather abstractly represent e.g. sense data. By this the ground was paved for the brain to *represent* the surrounding environment as well as the organism and the brain itself – in fact even the brain mapping itself mapping itself, the environment and the body and so on in a hierarchical succession. Maps about actual or recalled objects or actions in or outside the body are termed images, which is not to be understood as visual images but rather patterns created by any internal or external sensory modality. In other words, images occur as a result of the *momentary* mapping of an *interaction* between the

organism and an outside object, between the brain and the body or between parts of the brain with other parts of the brain [19].

Mind and self

In the terminology of neurobiology the mind is defined as the continuous, coordinated flow of such images. The patterns represent things and events located either outside the brain in the body or the external world, or inside the brain itself representing the brain's own processing of other patterns. Mind by this definition is a non-conscious process which is present even in fish and insects [20].

Consciousness appears when a self-process is added to the mind-flow as a knower in the form of an increasing degree of self-representation [21]. Just like the conscious states are not monolithic, the self-processes that produce them when added to the mind is not either. The first step in the self-hierarchy is the proto-self which occurs when the most stable aspects of the organism are mapped by specific brain stem nuclei in cooperation with cortical areas, perhaps most importantly the insula. The on-going mapping executed by the core-self mechanisms will moment by moment report the state of the organism on a range from the optimal to the problematic producing primordial feelings, which occur as a continuous experience of the life process, the homoeostasis, of one's living body "wordless, unadorned, and connected to nothing but sheer existence" [22]. Changes in the body state that occur e.g. as a result of an emotional program being launched are registered against the current state of the proto-self [23]. Thus, the self that orchestrates consciousness is "the first representative of individual life regulating mechanisms, the guardian and curator of biological value" [24]. The primordial feelings run at a scale that ranges from pleasure to pain, while "all feelings of emotion are complex musical variations on primordial feelings" [25].

The next level, the core self introduces the self as a protagonist, by adding a representation of the organism as it interacts with its environment, or in the words of Damasio: "What is being added to the plain mind process and is thus producing a conscious mind is a series of images, namely, an *image* of the organism (provided by the modified proto-self proxy); the *image* of an object-related emotional response (that is, a feeling); and the *image* of the momentarily enhanced causative object." [26]. Because of the

direct relationship of the proto- and core self to the body, they can be said as an entity to constitute the “material me” of the organism's here-and-now, while the autobiographical self rather constitutes the “social me” and the “spiritual me” [27].

The autobiographical self

The autobiographical self is about both personhood and identity. As implied by the term, what it adds to the core self is one's autobiography, both the lived past and the anticipated future. As such, autobiographical consciousness reaches the highest level of knowledge of one’s own existence [28].

To understand the autobiographical self, it is necessary to have a brief idea about how memory works. Memories are not stored as the end product of sensing, but rather as maps of the original sensory patterns in the early stages of perception as they originally occurred in the early sensory cortices. Remembering happens by the reactivation of these maps in the same early sensory cortices, meaning that memory doesn’t happen by recalling but by *reconstruction*. In this mechanism the old device of dispositional networks is combined with the new one of mapping, so that a much simpler dispositional network placed in so called convergence-divergence zones can activate the maps in the early sensory cortices, after which the sense data is run through the sensory machinery of e.g. the brain's visual system once again, resulting in the reconstruction of the original sense experience and resulting in a renewed adjustment to the core self-mechanism. Relatively few neurons in the activating dispositional networks of the convergence-divergence zone can then bind together maps in distinct early sensory cortices. In this way, a memory-reconstruction can be built, complete with emotional content and the resulting feeling states, sensimotor patterns of movement and touch, visual, auditory and olfactory experience. Especially the emotional component is important, as the emotional content constitutes a “value stamp” in the form of a “somatic marker” added to original perception, signifying the biological value [29, 30] . What we know as memory, imagination and thinking are in fact all variations of this arrangement, as the dispositional networks are able to manipulate and rearrange bits and pieces of the maps stored in the early sensory cortices and present them in the form of new thoughts and ideas. As the dispositional networks are unable to produce maps, their operations remain outside consciousness, and so do the basic operations of remembering, thinking and imagining.

Depending on the activation of this system, the awake mind will slide between states of pure core consciousness and core consciousness with autobiographical consciousness added.

Externalisation

The machinery behind the autobiographical self is a framework for handling a large amount of memory content in a very flexible and dynamic way; memory content that for the most part will have been acquired through the senses rather than being innate.

However, the fact that the processes of thinking, imagining and remembering basically rely on the same machinery as the senses allows for externalisation of memory. By this, external content capable of entering into the process either for its emotional, conceptual or thought related content can be stored externally and communicated between individuals even across generations [31]. The possibility for storing and sharing externalized memory content has given rise to phenomena such as the arts, religious rituals and myths, philosophy and science. In other words, the fact that the machinery responsible for the advent of autobiographical consciousness is a flexible framework rather than a fixed set of action programs, allows for the appearance of the dynamic phenomenon of culture. As the autobiographical consciousness is so dependent on the memory content available, the possibility of a development of human consciousness not dependent so much on biological evolution but rather on cultural development prevails [32].

Architecture

As it might be apparent, the question at all levels from the basic life regulatory mechanisms and emotions to the content of consciousness is about how the organism as a biological entity interacts with the world in a way that promotes its survival. To return to the categories defined by Pallasmaa in the beginning of this text: Existence literally depends on it in terms of Life and Death. For the organism, it is a question of handling the conflict between its interior and its exterior, in order to sustain its homeostatic balance. Architecture can now be seen as a kind of “externalised homeostatic defence”, an extra membrane formed by the building envelope, placed between the skin, the outer boundary of the organism, and its environment. By constructing an artificial, controlled

environment, the challenge of keeping the balance in the body's inner environment is greatly diminished. To a certain extent, the building envelope and the space it contains come to form an integrated system with the organisms in it. By this a hierarchy has been established. With the human body as the *defining cause,* construction must be seen as the *prerequisite* and the building envelope as the *means* and thereby *the carrier of existential meaning*. This suggests that architecture must emphasise the building envelope and the space it creates rather than construction, if it has to obtain its meaning from existential significance rather from some concept of beauty or some formal principle. An architecture understood in this way will be mirroring the basic homeostatic challenges to the organism that in the end holds its reason to be constructed. The implication will be an architecture of the dialectic between the stability of the interior and fluctuation in the external environment. It might add an existential layer to the old otherwise formal remark of Robert Venturi: “Since the inside is different from the outside, the wall –the point of change-becomes an architectural event. These interior and environmental forces are both general and particular, generic and circumstantial. Architecture as the wall between the inside and the outside becomes the spatial record of this resolution and its drama” [33]. This is not to say that construction as a class of architectural elements necessarily is insignificant, rather that they only gather their meaning as a prerequisite to the envelope.

By which means then will the building envelope carry its meaning? Just as consciousness has turned out not to be monolithic, so has the concept of architectural meaning, as architecture will influence the organism at many distinct levels from the simplest life regulatory mechanisms to autobiographical consciousness. By this, architecture mirrors the structure of the organism itself.

Basic life regulating mechanisms; Temperature, content of oxygen and carbon dioxide in the blood, air humidity; these are the simple things that are taken care of by heating, cooling and ventilation devices, either automated or manual. These basic life regulatory mechanisms are mainly about easily measurable amounts of e.g. oxygen, but as oxygen and other necessities are measured within the body, they are not as such connected to any direct perception of the environment. Though architecture influences this, it is merely indirect.

The emotional level; As the task of emotional action programs are to adjust the organism to the environment in order to enable it to cope with actual or anticipated disturbance of the homeostatic balance, it must be expected that emotional action programs are played out as a reaction to either the envelope itself or what is going on in the space created by it. As the emotional system seems to build its appraisal on the totality of events and environment [34], the building envelope will always be responsible for a part of the reaction. Because these action programs are "largely automated" [35], it must be expected, that they to a certain extent are predictable both concerning what triggers them and what the resulting bodily and behavioural reaction will be, those certain architectural patterns or "types" that triggers emotions might be found. Interestingly, as the task of emotional reactions is the adjustment of the body, the result might be a predictable bodily adjustment to space and envelope design. As emotional programs operate at a non-conscious level, subjects might not be directly aware of the reaction or that it has to do with the building at all, though it will eventually turn up as a feeling. As the emotional systems work very fast, the result of their reaction might be felt instantaneously. Quite in line with the recognition of the body-loop arrangement by neuroscience, Pallasmaa writes: "Sensory experience becomes integrated through the body, or rather, in the very constitution of the body and the human mode of being" [36].

Feelings: The changes made to the body and brain state by the emotional action program will be mapped by other structures turning up in consciousness as a feeling. However, as Damasio writes: "Consciousness offers a direct experience of mind, but the broker of the experience is a self, which is an internal and imperfect constructed informer rather than an external, reliable observer" [37].Thus the precise cause of events might not be perceived. Perhaps these feelings are rather what Zumthor refers to when he writes: "I enter a building, see a room, and – in the fraction of a second – have this feeling about it. We perceive atmosphere through our emotional sensibility – a form of perception that works incredibly quickly, and which we humans evidently need to help us survive" [38], or Gernot Böhme when he writes: "Perception is basically the manner in which one is bodily present for something or someone or one's bodily state in an environment. The primary "object" of perception is atmospheres." [39], where the perception of the "object" that produces the atmospheres eventually might by the perception of one's own body state that accompanies the emotional reaction to the perception of the object.

Core self: Via modification of the non-conscious proto-self, the conscious core self is changed as well. By this, as Juhani Pallasmaa once wrote: "We are in constant dialogue and interaction with the environment, to the degree that it is impossible to detach the image of the Self from its spatial and situational existence" [40]. In the case of architecture, the strange situation of a "reality-loop" comes into being, as a supplement to the body-loop that underlies the connection between emotions and feeling: 1) The artificial environment in terms of architecture is constructed consciously 2) the emotional system reacts to the artificial environment 3) The reaction is registered as a feeling, but because of the vagueness of the process, the feeling might or might not be directly ascribable to particular properties of the environment but rather be experienced as an atmosphere. 4) The feeling state becomes a part of the self.

Autobiographical self: It can create and hold externalized memory as related to the senses as combinations of visual content, light, smell, touch, sound, colour and patterns of movement. It can thereby be the carrier of culture and collective memory even across generations. The envelope can be the holder of symbols, like prehistoric cave paintings, the south-east wall in Le corbusier's Norte-Dame du Haut at Ronchamp or the overpowering amount of commercial symbols at the Las Vegas strip, or as stated by Pallasmaa: "…the art form of architecture does not only provide a shelter for the body, it also redefines the contour of our consciousness, and it is a true externalisation of our mind…..As we construct our self-made world, we construct projections and metaphors of our own mind scape." [41].

At least two conclusions can be drawn. First, it may be obvious from this list, that neurobiology might not revolutionise our concepts of architecture, as a surprisingly extensive correspondence between concepts of architectural theory which here have primarily been voiced through the writings of Juhani Pallasmaa, and those at the forefront of neurobiology (as represented primarily by the writings of Antonio Damasio). Thus, neurobiology as it develops will probably mean evolution rather than revolution to architectural theory. What it has to offer is perhaps an underlying framework of understanding, and importantly, it might help make the concepts of architectural theory researchable, lending architecture a voice in an otherwise evidence-driven society.

Second; the neurobiological understanding diverts the focus from the building's structural members towards the envelope as main carrier of meaning. It makes us understand how architecture through the senses can become memory content, and thus have the ability to carry externalised content of memory and consciousness. It adds to our understanding of architecture as a carrier of human culture. It makes us recognize that much of our transaction with architecture takes place outside the realms of consciousness, that by this the experience of architecture perhaps first and foremost involves the body, and that these non-conscious processes never the less have a profound though somewhat entangled influence on self and consciousness. It emphasises the dialectic tension between interior and exterior as the architectural advent. Architecture becomes more the act of enveloping than the act of construction.

The driving force behind the architectural drama of the existence of the envelope is exactly the contrast between the homeostatic demands that define its interior and the forces of the exterior environment. It must be an architecture that is equally aware of the interior and the exterior. Thus awareness of the building's context culturally as well as climatically is as important an understanding of the organisms that reside within it, in order to administer the transactions between the inside and the outside. As Gaston Bachelard wrote: “Behind dark curtains, snow seems to be whiter. Indeed, everything comes alive when contradictions accumulate” [42].

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